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POPLARS IN FORESTRY AND LAND USE

The paper used for this publication, which contains 20 percent poplar pulp, has been generously contributed to the International Poplar Commission by the "Cartiere Burgo" of Turin, Italy.

COMMONWEALTH MYCOLOGICAL INSTITUTE
15 SEP 1958

Line planting with *P.* ' marilandica '.

Courtesy *Nederlandse Heidmaatschappij*

FAO Forestry and Forest Products Studies *No. 12*

POPLARS

in forestry and land use

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS
Rome, 1958

The genus Populus *holds a very special place today among fast-growing species by virtue of its wide distribution, its suitability for cultivation both inside and outside the forest, and for the extensive range of products which it yields. Hence, the spread of poplar breeding and cultivation will help meet the ever-growing need for timber, while at the same time contributing to better land utilization.*

This study was prepared at the request of FAO by the Standing Executive Committee of the International Poplar Commission, under the direction of its chairman, Ph. Guinier. The work was co-ordinated by R. G. Fontaine, Chief of the Forest Policy Section, Forestry Division, FAO, and Secretary of the International Poplar Commission, and by J. Pourtet, member of the Standing Executive Committee.

The International Poplar Commission was established under the auspices of FAO at Paris in 1947 at the initiative of the French Government.

MARCEL LELOUP
Director, Forestry Division

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INTRODUCTION

The need for timber, the first raw material utilized by man, remains as indispensable in the twentieth century as it did in the early history of civilization.

Although other materials tend to replace timber in the building industry, for naval construction and the manufacture of various tools and implements, there are still areas of the world where, to a large extent, its use has not changed. Modern techniques, moreover, have now been devised for the transformation of timber and, consequently, new uses for it have been developed. For example, plywood and fibreboard are being used for construction purposes and for furniture; the paper industry and other trades are using increasing quantities of wood material, and wood has actually become a raw material for the chemical industry itself.

It is worth while at this point to review present-day timber resources and the prospects for future consumption.

Recent studies carried out by FAO's Division of Forestry indicate that the world forest area at present extends to some 3,800 million hectares, of which but 1,150 million hectares, scarcely one third, are being exploited. Therefore, while it would appear that a vast proportion of the world's forest resources remain as yet untapped, it should be borne in mind that the greater part of these forests cannot be considered as economically productive, either because they serve a primarily protective purpose, or because they are far removed from the centers of consumption.

In *World Forest Resources*, an FAO publication, it has been established that in the 600 million hectares of exploited coniferous forests, annual increment and fellings more or less balance, and that the remaining virgin forests are inaccessible. As softwoods are more suited to market needs, there will be an increasing demand for them in an expanding world economy and, generally speaking, the demand for timber and timber products, especially of small-sized timber in the round, will rise very rapidly. It has been estimated, for example, that pulpwood requirements after 1960 will rise to 260 million cubic meters as against approximately 180 million at the beginning of the decade 1950-60, while another study for Europe, *European Timber Trends and Prospects*, prepared jointly by FAO and the Economic Commission for Europe, has shown that the annual consumption of timber and industrial wood in the years to come will exceed by 30 to 40 million cubic meters the annual estimated production of 150 million cubic meters.

To grow as much timber as possible, and to grow it quickly, is therefore an urgent necessity today in many countries and, it might be said, an obligation in the world as a whole. Poplars can make an important contribution to this program. They have a rapid growth rate: the forms most commonly grown can profitably be utilized from 20 to 25 years, and sometimes earlier. Their wood is well suited to industries which are at present undergoing rapid expansion, such as in the manufacture of veneers, light boxmaking materials, fibreboards, paper pulp. From the point of view of soil utilization, poplars make use of land which is unsuited to agriculture; on the other hand, established in certain types of forest stands, they are capable of increasing productivity. They also have a further advantage, in that they can be cultivated in various ways in association with farm crops. Poplars are, in fact, the timber producers of countries lacking forests, and it is not without reason that in the treeless countries of the Near East they are known as "blessed trees." Interspersed on cultivated land, they provide the population with firewood and timber; in addition, they constitute a veritable "savings bank" which can be realized when the time comes to fell them in order to improve the property as a whole.

Poplars have long been cultivated in widely different regions of the world. In the East, their cultivation would appear to date to very early times. In Europe, too, there are countries where poplar growing has a very long history but it is chiefly since the eighteenth century, when North American poplars were imported to hybridize with native European poplars, that the cultivation of poplar began to expand. Throughout the nineteenth century and at the beginning of the twentieth century, cultivation has made rapid strides, and during the last few years the trend has even gained momentum. In several European countries, in the Near East, as well as in temperate regions throughout the world, interest in poplars is growing: efforts are being made to cultivate them more scientifically over wider areas, as well as to introduce them into regions where they are only slightly known, or even completely unknown.

Where poplar growing is widespread, cultivation follows an established tradition and more or less rational practice. In the present age, however, the cultivation of all the plants which man needs depends for increased productivity on scientific research and experiment. In order to grow any plant profitably, precise knowledge of both its biology and environment is essential: from this knowledge the best cultivation techniques can be determined. It is logical to apply to poplars the methods which have achieved success in agriculture; poplars should therefore be studied in detail and the most profitable methods of cultivation selected.

* * *

The program thus outlined is an ambitious and difficult one to implement. Poplars in fact have certain features which set them distinctly apart from other timber-producing trees. These features derive from three circumstances: poplars are propagated primarily by vegetative means and not from seeds; they are dioecious; and for this reason hybridization is common between trees of different varieties and opposite sex.

Unlike tree species which are reproduced from seed, cultivated poplars are normally propagated from cuttings. Consequently, when any particular stem is observed to have qualities which make breeding worth while, it is a simple matter, by taking successive cuttings, to produce an indefinite number of trees bearing identical characteristics. This is the origin of the enormous number of forms to be found among cultivated poplars. As a general rule, a study of forest trees reveals *species* or *varieties* composed of a collection of stems having a large number of characters in common but perhaps differing in a few details; these are so many *individuals*. This is also true of poplars occurring naturally, which include male and female stems and which multiply by seeding. But in the majority of cases, and in practice the most interesting as regards cultivated poplars, a group of stems with the same characters consists of a single *individual* which has been split up an indefinite number of times. This is what is meant by a *clone*, and is a peculiarity of poplars which has often been misunderstood and which must be borne in mind.

Poplars are dioecious; therefore, it frequently happens that when two trees of different forms and opposite sex are adjacent, cross-fertilization occurs, and the seeds thus formed produce hybrids. It is a well-known fact that, due to the phenomenon of *heterosis*, hybrids are generally more vigorous than the parent trees. It is therefore natural that poplar hybrids, produced spontaneously at different times and in different places, should occasionally have attracted the notice of cultivators who have reproduced them; hence a large number of poplars of quite ancient origin in different countries are hybrids. But instead of merely using natural hybrids, there is no reason why new hybrids should not be created. This has already been done by sowing seed collected from trees planted in conditions which facilitate hybridization. Another means is by artificial fertilization. This is a simple operation which consists of adopting a natural method based on the flowering and seed-forming characteristics of the poplar. In this way plant breeding methods in current use in agriculture can be applied to poplars, thereby deriving new forms with high productive capacity.

The basic characteristics of poplars are the cause of all the difficulties encountered when they are identified and classified. The botanist is faced with innumerable forms which are, generally speaking, no more than clones derived from the same species or from hybrids. These forms may closely resemble each other. They can, in fact, sometimes only be distinguished one from another by a careful examination of the factors which are normally not taken into account in the study of trees; for example, particular attention should be given to the relative date of leafing, the color of the young foliage and the habit of the tree. These factors account for the confusion which has existed, and still exists, in the common nomenclature of poplars, as well as for the inadequacy of scientific poplar research. In countries where poplar growing is well established, the inaccuracies of nomenclature can be observed; the same name may be attributed to different forms, or conversely, the same type is given different names, according to the region.

Botanists engaged in the study of poplars have frequently described clones as species and have failed to recognize the hybrid nature of many of them. On the basis of the data available, the task is to define the principles of poplar identification and to establish a logical and accurate nomenclature in conformity with the international rules for botany and horticulture. Thus, it will be possible to recognize poplars, distinguish between species, varieties and clones and name them in a uniform manner. Yet such knowledge is insufficient from the botanical point of view, since other considerations must be recognized when they are to be cultivated for profit and where the aim is to obtain the highest possible yield. First, ecology, reactions to climatic conditions and soil requirements must be known. This information will enable the planter to select for all sites the clones best suited to local conditions and most likely to thrive. On the other hand, it is important to grow timber-producing types of maximum industrial value; hence the physical, mechanical and chemical properties of the timber of the various poplar forms should be studied in accordance with modern research methods and their suitability assessed for the various purposes which industry reserves for poplar wood.

Knowledge of poplars alone is not sufficient; it is necessary to know how to grow them, and this gives rise to a variety of problems. In the different countries where they are grown, cultivation is governed by traditional practices, some of which, both logical and accepted from long experience, can be recommended, whereas others are open to criticism and do not give the best results. Scientific and experimental study of methods of cultivation should therefore be made of the complete life cycle of the tree from the time the cuttings are put in the ground and the young plants raised, to their final establishment on the site and the care given them during their development.

Finally, plant cultivation of any kind is exposed to damage, sometimes by external agents but more often by attacks by plant or animal organisms. The study of poplar pathology and the means of protecting the trees against their enemies is an indispensable adjunct of successful cultivation.

A thorough knowledge of poplars and their cultivation is therefore the primary aim. Yet this has only been recently recognized, as poplars were long neglected by scientists, agriculturists and foresters. Botanists did not understand the fundamental characters of the genus, which preclude the application of the normal principles of systematic botany. Growers with inadequate botanical knowledge at their disposal restricted themselves to describing cultivation practices in their particular region, without applying any degree of critical judgment or experimental initiative. Only quite recently have authors started to distinguish between varieties and describe the poplars of their own countries. In this respect mention should be made of Dode (France, 1905), A. Henry (Great Britain, 1914) and G. Houtzagers (Netherlands, 1937). In Italy, the *Istituto di Sperimentazione per la Pioppicoltura*, at present under the direction of G.Piccarolo, is given over exclusively to the study of Italian poplars, and particularly to research into the creation of new forms and experiments on the best cultivation methods. In Germany, Dr. Bauer has carried out research and experiments on various types of poplars and their cultivation in the forest under a variety of conditions. Wettstein in Austria and Helge Johnsson in Sweden have made a special study of poplars of the aspen group (*Populus* subsect. *Trepidae*).

For several years now poplars have been rapidly coming to the fore. The problem of increasing timber production gave rise in France to the creation in 1942 of a National Poplar Commission attached to the *Direction générale des eaux et forêts*, which has undertaken the study of French poplars and research to determine the best methods of cultivation. In 1947, it was decided to convene a meeting in Paris of representatives of a number of European countries interested in poplar growing and, after a study tour of the largest poplar plantations in France, and an exchange of views, it was decided to set up an International Poplar Commission within the framework of FAO. This Commission has been in active operation ever since.

An increasing number of countries have jointed the Commission, or partaken in its work, and national poplar commissions have been organized in various countries for the purposes of research and publicity. From 1948 to 1955, international congresses and meetings have been held in Italy, Belgium, the Netherlands, England, Germany and Spain, and in the course of these meetings many problems have been discussed and valuable information assembled as a result of study tours. Furthermore, a permanent committee, composed of a restricted number of members, has been meeting at more frequent intervals. On the whole, this co-operation has considerably promoted knowledge of poplar forms and methods of cultivation. It has also helped contribute information in regard to nomenclature, registration of forms, varietal control, exchange of cuttings and utilization.

The purpose of the present volume is to make available to agriculturists and foresters the results of the research accomplished and to co-ordinate the facts and opinions on which agreement has been reached.

* * *

G. Houtzagers (Netherlands) and J. Pourtet (France) have prepared the chapter on classification, identification and distribution of poplars, in which an effort has been made to describe the botanic characters, ecology and cultural importance of the various species and varieties, as well as the most commonly cultivated clones. This summary, which includes the work of several authors and comments from the Netherlands, France, Italy and the United States of America, does not presume to contribute a complete list of existing poplar forms which can be grown in the various parts of the world climatically suited to poplar. Forms of poplar which are still imperfectly known may have a limited interest, and certain ecological features need to be confirmed by experiment. For example, it is often difficult to predict the reaction of a particular form to a climate which differs considerably from that in which it normally grows; therefore, investigation of special cases, as well as completion of research already initiated still remains to be done. Nonetheless, the course has been plotted.

The discovery or creation of new forms adapted to specific sites and having a rapid rate of growth is the soundest way to improve and extend poplar cultivation; for this purpose, a knowledge of poplar genetics and breeding methods is essential. Helge Johnsson (Sweden), who has made a special study of this question, has contributed a section on this subject to the present volume.

The International Poplar Commission has given particular attention to the question of the technological properties of poplar wood, the defects which prejudice its use and the purposes for which it is suitable. This range of subject matter has been treated by G. Giordano (Italy), wood technologist, who has presented a fully documented study of the properties and defects of poplar wood, and this is the first time that this subject has been broached. Details of felling and extraction methods, as well as the industrial uses of timber, complete this chapter.

Poplar cultivation is considered from two points of view: its intensive and extensive aspects.

In intensive culture, the aim is to establish poplars in the most suitable conditions and to give them all the care necessary to ensure maximum yield. Intensive cultivation can be practiced in the form of sustained yield with crops, or in rows alongside roads or watercourses. An account of the technique to use, from the cutting stage in the nursery to the age at which the trees can be felled, has been described by A. Herbignat (Belgium) and G. Piccarolo (Italy). The methods outlined are those which are considered best and which experience in different countries has confirmed as most desirable. Some examples were taken from the Po Valley in Italy, where poplar growing has attained a high degree of efficiency as a result of systematic experimentation. Naturally, methods may vary with climatic conditions, and techniques will need to be developed to keep pace with new circumstances.

Poplars can also be grown extensively in the forest. In some regions, they grow naturally alongside watercourses; elsewhere, they can be planted in mixed forests with other species. And, in view of their rapid growth, the revenue from the forest can be appreciably increased.

In this study, F. W. Bauer (Germany) and E. Gaillard (Switzerland) have contributed a section on this method of growing poplars. This technique is particularly important in alluvial forests. The method to adopt and the results which can be obtained are described on the basis of examples taken from the Rhine Valley, where natural forests of low productivity have been successfully improved by planting poplars. In some rare cases poplars may also find a place in other types of forest — and H. Leibundgut has contributed to this particular question.

Knowledge of the diseases which may attack poplars and the damage to which they are exposed from animals, is of prime importance. Diseases due to external causes or fungi are discussed by T. R. Peace (United Kingdom), specialist of forest tree pathology. F. Régnier (France), who has made a special study of animals which cause injury to plants, has dealt with damage caused by animals, and particularly insects. An effort has been made by these two authors to assemble all available information extant on the subject of enemies of poplar and measures of control. However, it should be noted that the very nature of these pests and the extent of their damage varies considerably according to the region: a disease which is dangerous in one area may be of negligible importance a short distance away and, similarly, an insect which is particularly detrimental in one country, may be unknown elsewhere. It should also be observed that, as cultivation expands, there is always the risk that some diseases or insects may reappear or increase in virulence.

The authors responsible for the various chapters, submitted their texts in draft to the Standing Committee of the International Poplar Commission. The texts were carefully examined and discussed at several meetings, and unanimous agreement was reached on certain changes and additions.

R. G. Fontaine (FAO), Secretary of the International Poplar Commission, assumed the difficult task of establishing liaison among authors, of co-ordinating their work, and finally seeing to its publication.

In order to avoid excessive text and redundancy, names of authors consulted appear only in the bibliographical section and are not referred to in the text itself.

* * *

The present study is the result of teamwork and friendly collaboration amongst members of the Standing Committee, with the sole interest of furthering the cause of forestry. The facts presented and the ideas formulated, based on observation, experience and deduction, have been accepted by all concerned. It is hoped that this joint enterprise, which has received the strong support of the Director of the Forestry Division of FAO, may contribute to the improvement and extension of poplar cultivation throughout the world.

PH. GUINIER
Chairman, International Poplar Commission

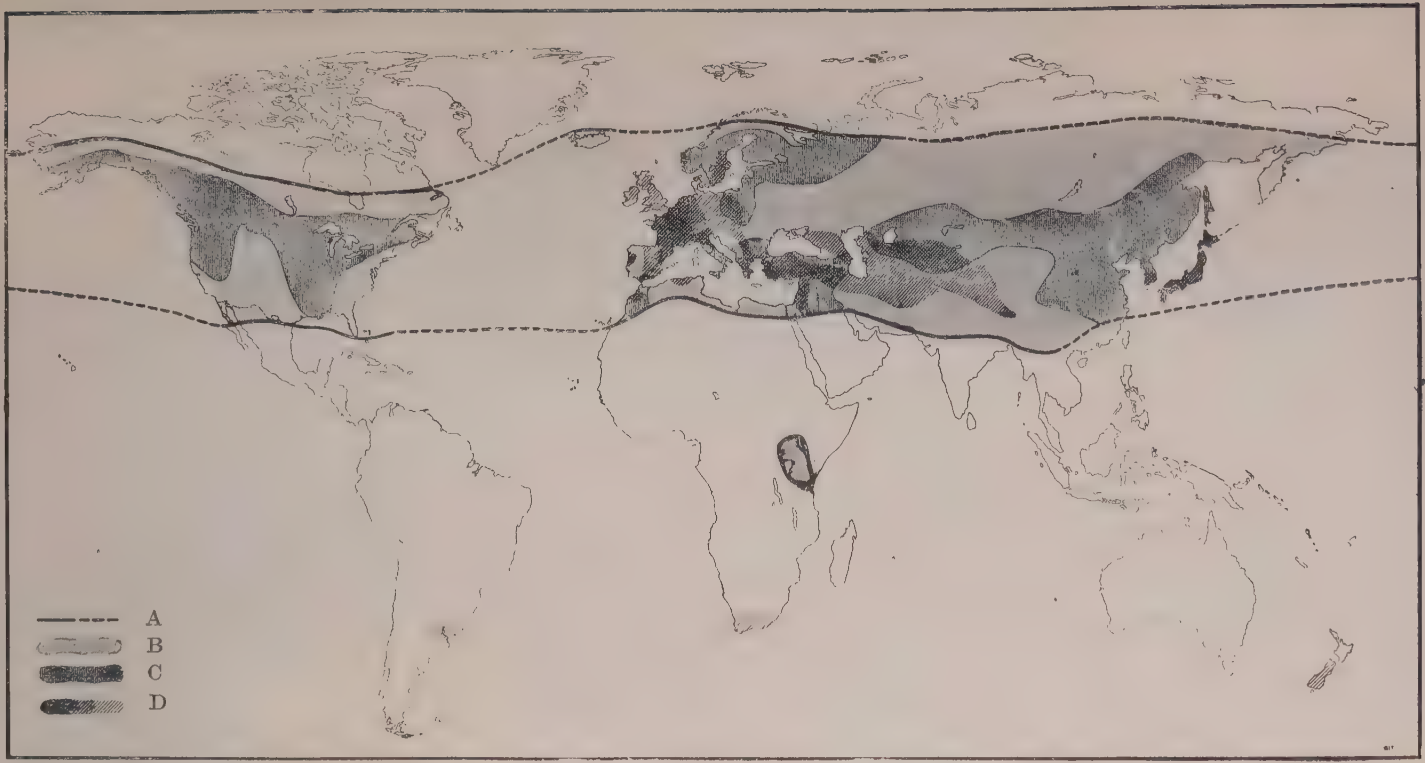


FIGURE 1. – World distribution of poplars.

A - Limits of the natural distribution area of the genus *Populus*.
B - Natural distribution of the genus *Populus*.
C - Zones where poplars are of particular importance.
D - Principal areas of poplar cultivation (little is known of their importance in eastern Europe and central Asia).

CLASSIFICATION, IDENTIFICATION AND DISTRIBUTION OF POPLAR TYPES

The characteristics of the genus *Populus* have been described in the introduction; while they account for the great interest in its cultivation, at the same time they complicate any study of the genus, and as a result considerable confusion has existed in its taxonomy. Although many careful studies have been published on the subject of the botanic classification of poplars — particularly in the last 25 years — these have generally covered only a rather limited region. Today the field of activity is constantly expanding, due in particular to international collaboration fostered by the Poplar Commission, and it has therefore become necessary to add to the known list of poplars new species, and especially new clones and hybrids, which would appear lacking in importance for a more limited area.

The essential aim of this chapter, therefore, is to introduce, on the basis of the earlier works mentioned above, a logical order into the ever-increasing number of forms of poplar. It is of course impossible to develop a system under which all these new forms and hybrids (often of an origin still too recent) can be grouped but it will suffice to consider the present situation in relation to the system in vogue which will, if necessary, be brought up to date.

I. BOTANICAL CLASSIFICATION: ORDER, FAMILY AND GENUS

The genus *Populus* belongs, together with the genus *Salix*, to the family *Salicaceae*. This family is of the Order *Salicales*, one of the four which make up the group *Amentiflorae*. The *Amentiflorae* are characterized always by unisexual flowers and by male flowers together in catkins. The ovary contains from 2 to 6 carpels; the perianth is either absent, or insignificant and inferior. The order *Salicales* is characterized by dioeciousness and by a capsular fruit opening by valves. The *Amentiflorae* fall within the subclass *Monochlamydeae* (plants without perianths or with a simple perianth) of the *Dicotyledoneae* class, subdivision *Angiospermae,* division *Phanerogamae.*

In the case of the *Salicaceae,* the male and female flowers are arranged in catkins. The ovary contains from 2 to 4 stigmas on a style, which is short and sometimes sessile. The fruit consists of a dehiscent capsule with valves, and the seeds contain a white pappus resembling cotton.

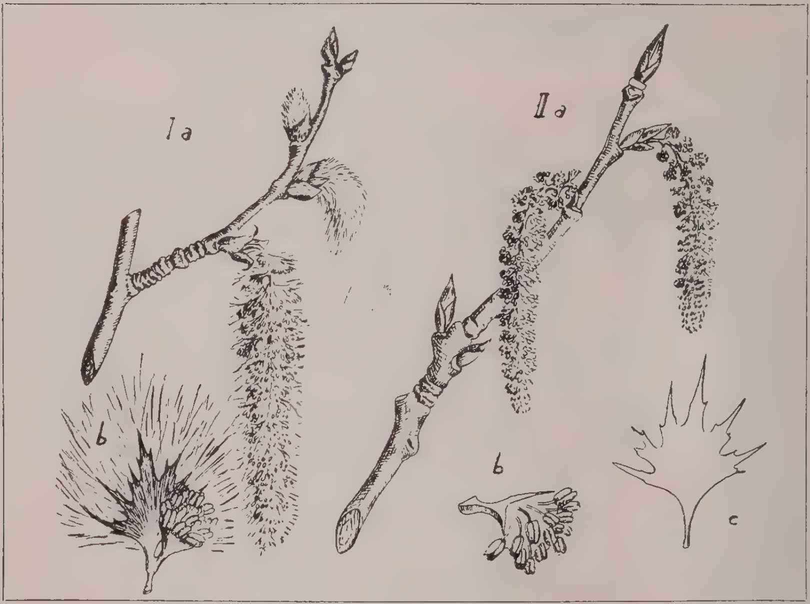


FIGURE 2. – Male catkins

I *a*) Male catkins of *P. tremula*
b) Male flower of *P. tremula* with ciliate bract; stamens contained in cup-shaped perianth

II *a*) Male catkins of *P.* 'serotina'
b) Cross section of a male flower of *P.* 'serotina'
c) Nonciliate bract, falling during the flowering period

The leaves are simple, spiral and alternate with a divergence of two fifths. However, in the case of the genus *Populus* it must be noted that the leaves are polymorphic, a feature which is more or less marked in the different sections and according to their position on the tree:

Leaves on short shoots: generally smaller and less lobed than the others, they are the first to appear in the spring and are to be found almost exclusively on old trees or trees with little vigor.

Leaves on long shoots: situated higher up than the former, they are found exclusively on young growth, stump shoots, root suckers, etc.

Both willows and poplars are light-demanding species, whose natural habitat is generally lowlying and moist ground. They can tolerate winter flooding for a time but are nearly all affected by stagnant water and are only rarely found in acid and peaty soils.

The two genera may be differentiated by the characters given in the following table:

TABLE 1. - DISTINGUISHING CHARACTERS OF THE GENERA *Populus* AND *Salix*

	Poplar *Populus*	Willow *Salix*
Leaves	Generally triangular-rhombic but sometimes round or lanceolate, always with a long petiole; leaves often vary in shape depending on shoots	Lanceolate with short petiole uniform in shape
Buds	Several overlapping scales; terminal bud larger than lateral buds	Single scale; terminal bud absent or little developed
Shoots	Round or angles with pentagonal pith	Round, with round pith
Inflorescence, etc.	Always appears before the leaves; catkins pendulous, without nectaries (pollinated by wind)	Either before or after flushing, catkins erect, with nectaries (pollination by insects)
	Perianth oblique, cup-shaped	Perianth absent
	Bracts with toothed scales, glabrous but sometimes with fine hairs in the angles (*Leuce* section); usually fall during flowering	Bracts entire, hairy; do not fall during flowering
	Catkins male, reddish in color due to the red anthers	Catkins male, nearly always yellow in color due to yellow anthers

The genus *Populus* is divided into five sections:

1. Section *Turanga* Bge.

Typified by the polymorphism of its leaves, which are grayish and leathery with cylindrical or sometimes slightly compressed leafstalks, and by its downy buds. Male flowers have 8 to 12 stamens, female flowers 3 stigmas.

TABLE 2. - DISTINGUISHING CHARACTERS OF VARIOUS SECTIONS OF THE GENUS *Populus*

Section	Subsection	Leaves	Leafstalks	Buds	Flowers (male)	Flowers (female)	Fruit
TURANGA		very varied	in section rounded or flattened near the blade	pubescent	large red catkins - 8-stamened	large green catkins - 3 red stigmas	3-valve capsule
LEUCE	*Albidae*	on short shoots small, elliptic to round; on long shoots lobed; white tomentose beneath	shortish and round (slightly flattened near the blade)	small, pubescent	catkins 8-10 cm., 6-10 stamens	catkins ± 5 cm., 4 stigmas	2-valve capsule
	Trepidae	round or ovate with nonpersistent hairs	flattened	small, adpressed and lustrous, occasionally grayish (*P. grandidentata*)	catkins 8-10 cm., 5-20 stamens	catkins 10-12 cm., 2 stigmas	2-valve capsule
AIGEIROS		deltoid, triangular or rhombic with translucent margins	flattened	lustrous	12-60 stamens	2-4 stigmas	2-4 valve capsule
TACAMAHACA		ovate, length greater than width, base round; undersurface has metallic luster	in section, round	large, viscid, aromatic	15-60 stamens	2-4 stigmas	2-4 valve capsule
LEUCOIDES		large, heart-shaped	in section, round	more viscid, lustrous	12-30 stamens	2-3 stigmas	2-3 valve capsule

2. Section *Leuce* Duby

Round or ovate leaves, sometimes lobed. The trees for a long time retain a smooth, greenish white or grayish white bark. The base of old trees has a rhytidom which is shallowly fissured into large plates. The bracts have white hairs in their notches making the catkins appear white and furry when opening. The bracts do not fall during flowering. Male flowers have 5 to 20 stamens. The capsule is long and staight, generally with 2 valves.

The Section *Leuce* is divided into two subsections:

a) *Albidae* - White poplars, Chopos blancos, Peupliers blancs, Weisspappeln, Pioppi bianchi

Leaves on short shoots are elliptic to round, the underside at first clothed with a white or gray down but occasionally soon becoming glabrous. Leaves on long shoots are more or less lobed, white or gray tomentose beneath, as are the leafstalks, young branchlets and buds. The leafstalks of lobed leaves are almost round and flattened toward the blade; those of round leaves are flatter.

b) *Trepidae* - Aspens, Trembles, Chopos temblones, Aspen, Tremoli

Leaves are suborbicular or ovate, glabrous — even on the underside — or downy, but only during the period of flushing. Leaves on long shoots are often slightly larger and less round than leaves on short shoots. The petiole is compressed and perpendicular to the leaf blade. Buds, young shoots and petioles are usually glabrous.

3. Section *Aigeiros* Duby - Cottonwoods, Chopos negros, Black poplars, Peupliers noirs, Schwartzpappeln, Pioppi neri

Leaves are triangular or rhombic with both surfaces green and generally glabrous, their margins translucent, finely toothed or serrate, the leafstalks compressed. Buds, leaves and petioles are usually glabrous, the buds and young shoots at first slightly viscid. The bracts are not hairy in the angles, with the result that the catkins, unlike those belonging to the *Leuce* group, are glabrous, and so appear more slender. The bracts fall at the time of flowering. Male flowers have 12 to 60 stamens. The capsule is more globular than in the case of the *Leuce* group and opens into 2 or 4 valves. The rhytidom is thick, coarse and furrowed longitudinally.

4. Section *Tacamahaca* Spach. - Balsam poplars, Chopos balsámicos, baumiers, Balsampappeln

The leaves in general are rather ovate or lanceolate, often large, longer than they are broad, with a round or heart-shaped base, glabrous and white with a metallic luster on the underside and bright green above. The leaf margin is serrate or toothed, not translucent; the petiole is round and often ridged on top. The buds are large and, like the young leaves when they open, viscid; they give out an aromatic exudation from which they get the name " balsam poplars." The young branches bear a large number of short shoots. The bracts are not hairy in the angles and fall during flowering. Male flowers have 15 to 60 stamens. The capsule opens into 2 to 4 valves. With age the tree develops a deeply ridged rhytidom, as in the case of poplars of the *Aigeiros* group.

5. Section *Leucoides* Spach.

The leaves are large and heart-shaped, the leaf margin not translucent. During flushing the leaves are covered with a grayish hair but often soon become glabrous except along the veining of the undersurface. The bracts are not hairy in the angles and fall during flowering. Male flowers have 12 to 40 stamens; the style is longish and the capsule has 2 or 3 valves. The rhytidom is rough and slightly scaly.

II. DETAILED DESCRIPTION OF THE PRINCIPAL POPLARS IN EACH GROUP

In a general study on the growing of poplars, it is necessary to give first of all an adequate description of the material used in poplar cultivation, that is to say, information as complete as possible on the taxonomic and botanic characteristics of the most important species, varieties and hybrids. It has also been thought necessary to give here some special details of their ecology, resistance to disease and insect pests, and often also of their possible utilization, although all these questions are dealt with in more detail in the chapters which follow.

It should be noted that the species, varieties and hybrids described below represent only a selection of the vast quantity of material which exists. Some unimportant, obscure or badly defined species and forms have been omitted altogether or have merely been mentioned in passing. A large number of cultivated forms and particularly hybrids, although sometimes well known in certain regions, have also been omitted, either because they have been considered obsolete or of insufficient importance, or because they have not been sufficiently well defined or adequately tried out. In some cases, acute susceptibility to certain diseases has been the reason for an omission (for example, canker in the case of *Populus* " brabantica " and " McKee " poplar).

It should be mentioned here that in this genus, where vegetative propagation is generally easy, there are two categories of trees: on the one hand, the species or their natural subdivisions, that is to say, the slightly homogeneous populations where both sexes are evidently present and, on the other hand, the forms (hybrids or otherwise) which only propagate vegetatively and which are thus very homogeneous and represented by a single sex. If in the descriptions which follow no mention is made of the sex, it is implied that both male and female trees are to be found. On the other hand, the most important hybrids are either male or female.

In accordance with the decisions of the International Poplar Commission, the nomenclature used throughout this study conforms to the International Code of Botanical Nomenclature (Stockholm 1950) and the International Code of Nomenclature for Cultivated Plants (London 1952). It distinguishes, on the one hand, between the species, subspecies and natural varieties which are denoted by Latin names (*in italics*) followed by the name of the author; for example, *Populus deltoides* Marsh. ssp. *monilifera* Henry, or *P. nigra* L. var. *betulifolia* Torr.; and, on the other hand, the cultivated varieties or cultivars (cv.), which are subdivisions of the former and are known by " fanciful " names without the name of the author; here the Latin or vernacular names are distinguished typographically from the preceding names by single inverted commas; for example, *Populus nigra* L. cv. ' italica ' or *P. nigra* L. cv. ' Hamoui '. It is these cultivars which are generally of one sex only.

A. SECTION *TURANGA*

This section, while represented chiefly in central and western Asia, is also distributed in scattered areas along the southern and western fringe of the Mediterranean. In spite of the extent of this geographic distribution, it does not seem possible to distinguish several species as Dode has done, since the particular characteristics which he attributes to them may also be observed among trees in the same stand. Moreover, some of them may be considered as geographical forms of the main species.

POPULUS EUPHRATICA Oliv. = *P. diversifolia* Schrenk (including *P. ariana, mauritanica. bonnetiana. litwinowiana. glaucicomans, illicitana* and *denhardtiorum* Dode. *P. pruinosa* Schrenk) Gharab - Palk - Saf-Saf

Distribution

It extends from the Altai Mountains (45º 1′ N.) to Kenya (Equator: *P. denhardtiorum*) and to the west as far as Spain (*P. illicitana*) and western Morocco.

It is to be found chiefly in Turkestan, Iran, Iraq and Syria, where natural stands are of a certain economic importance, and also in Turkey, Pakistan, Palestine, Egypt, Libya, Algeria, etc.

Distinctive characters

Habit and dimensions: rarely straight and slender, often bushy. A tree usually of medium height, capable of attaining a diameter of 70 centimeters under good conditions.

Shoots: rather thick, more or less pubescent.

Leaves: grayish-green and leathery, extremely polymorphic.

Long-shoot leaves: triangular to rhombic with glands at the base of the blade (on root suckers and stump shoots, lanceolate, linear and entire, resembling those of eucalypts, or more or less lobed).

Short-shoot leaves: suborbicular, broad, strongly toothed at the apex (resembling aspen leaves).

Bark: olive-green, fissuring into a thick, fibrous rhytidom, ridged longitudinally.

Ecology

Very light- and heat-demanding, at least in the summer, *Populus euphratica* can tolerate extremely arid and " continental type " climatic conditions, provided the soil has a good supply of water, even if this is brackish. It can in fact tolerate a high degree of salinity; it appears that certain populations are more halophilous than others. In the Near East it is subject to attack by various beetles of the genus *Capnodis* and by *Cuscuta monogyna.*

FIGURE 3. – *P. euphratica* at Settat (Morocco).

Courtesy *J. Pourtet*

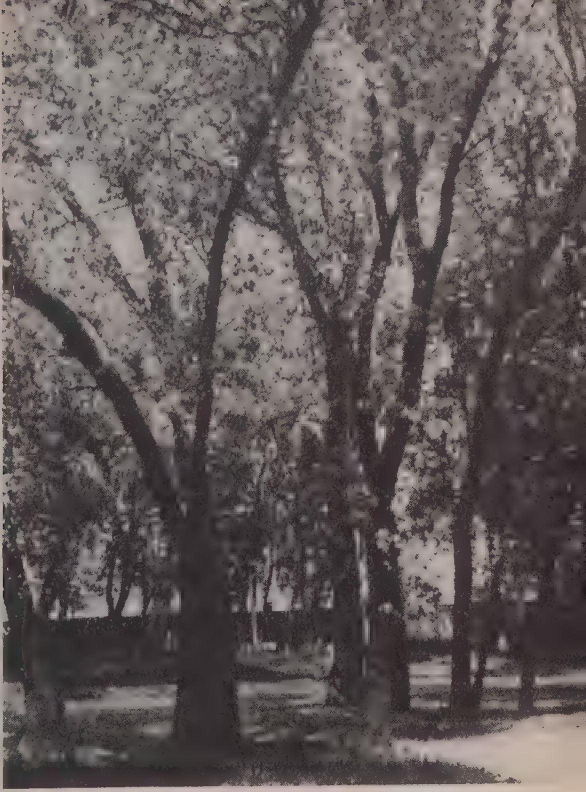
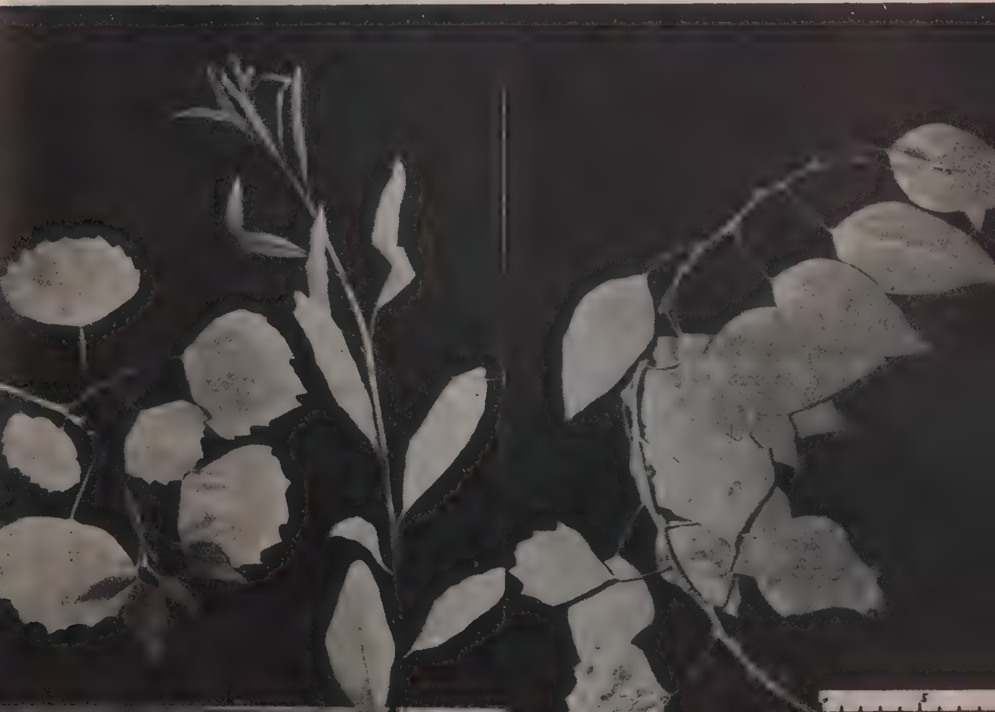


FIGURE 4. – Leaves of *P. euphratica* at Settat (Morocco): left, leaves on short shoots and young leaves on long shoots (spring); center, leaves of suckers; right, a leafy shoot in autumn; at base, short-shoot leaves; at top, long-shoot leaves.

Courtesy *J. Pourtet*



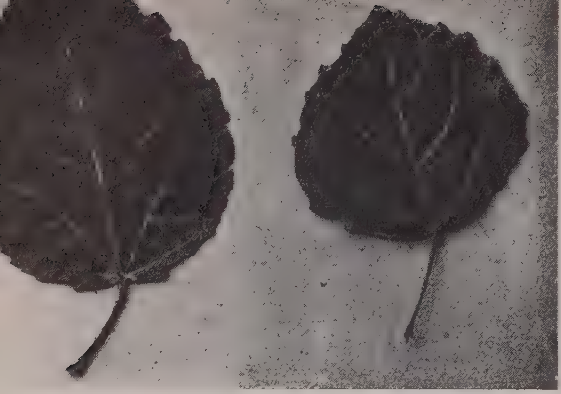
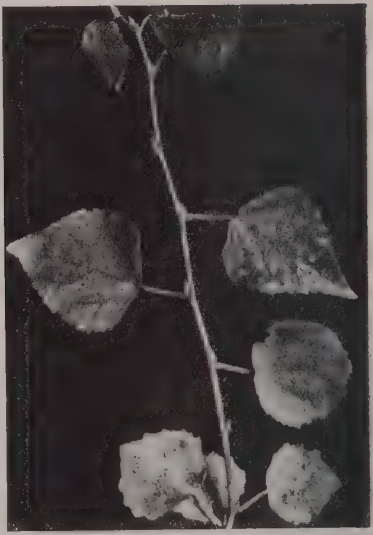


FIGURE 5. – *P. tremula* var. *villosa*. Lowland variety of western Europe. Left, leaf from long shoot; right, leaf from short shoot.

Courtesy *J. Pourtet*

FIGURE 6. – *P. tremula* L. Arrangement of the two types of leaves on shoot.

Courtesy *J, Pourtet*



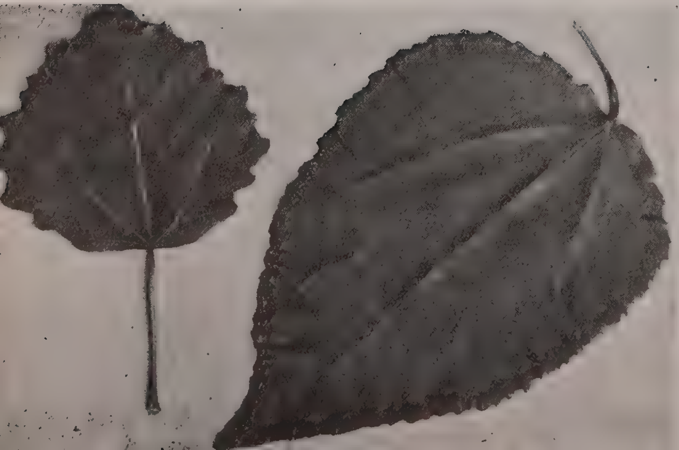


FIGURE 7. – *P. tremula* L. Mountain strain found in western Alps. Left, long-shoot leaf; right, short-shoot leaf.

Courtesy *J. Pourtet*

Growth characteristics

It throws out stump shoots and root suckers vigorously. It is rarely propagated artificially (as for example in Iraq, in the Agadir dunes of Morocco, etc.) but it can be propagated by cuttings.

The Euphrates poplar can make a useful contribution to the timber needs of peoples in arid regions, especially where the salinity of the soil precludes other types of cultivation, but improvement of existing stands and a selection of their best strains are essential before it can be given an important place among poplars.

B. SECTION *LEUCE*

This section is divided by dendrologists and silviculturists alike into two subsections: the aspens (*Trepidae* Dode) and the true white poplars (*Albidae* Dode).

Throughout the Northern Hemisphere the aspens cover an immense, compact area from the polar circle to the 40th parallel, extending even further south in certain mountain ranges. Their ecological, technological and growth characteristics are sufficiently homogeneous to be applied to the species as a whole.

Ecology

Aspens are extremely light-demanding, unaffected by low temperatures and, while indifferent to the type of soil, do not reach their best size except in deep, fresh soils.

Their typical habitat is open ground (particularly fire sites or burned areas) owing to their light seed and considerable suckering ability: they grow fairly rapidly but are relatively shortlived (about 100 years). They do not stand up well to competition from other trees therefore, but can form dense pure stands or mixed stands with birch. Their root system is shallow and they are therefore not wind-resistant. They are frequently attacked by wood-rotting fungi.

Growth characteristics

Regeneration is chiefly by root suckers but also by stump shoots and seed. Artificial propagation by cuttings is very difficult, or even impossible using current methods and, therefore, propagation is carried out either by transplanting suckers or from seed, the latter germinating well under glass.

Artificial regeneration of aspens is therefore rarely practiced.

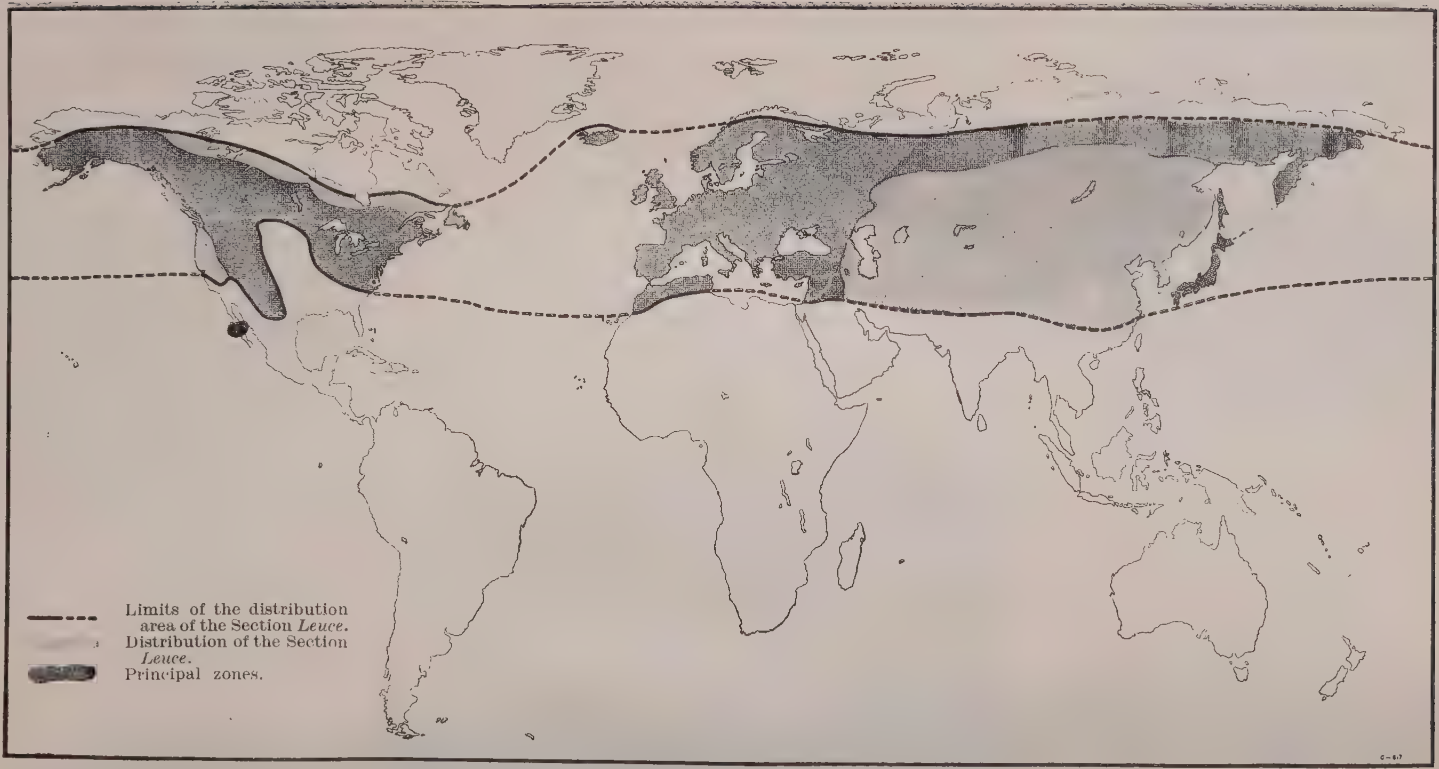

Limits of the distribution area of the Section *Leuce*.
Distribution of the Section *Leuce*.
Principal zones.
C-8.7

FIGURE 8. – World distribution of white poplars.

POPULUS TREMULA L. - Aspen. Tremble. Zitterpappel

Distribution

This species is found over a vast area throughout almost the whole of Europe with the exception of the southern plains (in the regions bordering the Mediterranean aspens are only found in mountain areas such as the Pyrenees and the Alps, and the mountains of Algeria, Italy, the Balkans and Asia Minor). It extends as far as the northeast of Asia where certain forms are sometimes raised to the rank of species.

It is of considerable economic importance in northern regions but of much lesser and disparate importance elsewhere.

With such a vast distribution, which is comparable with, but even greater than, that of *Pinus sylvestris*, varieties, or at least local types of *Populus tremula* have evolved and can be grouped into two main categories: one a northern and mountain type, and the other a lowland type found in central and southern Europe. The morphological features of these groups are given below.

Northern or mountain type	Lowland type (sometimes considered to be a variety: *P. tremula* var. *villosa* Lang.)
Scandinavia, Poland, Alps, etc.	France, Italy, etc.
Type described: French Alps (Savoy: 1,800 meters)	France (Paris basin)
Habit: slender, crown conical or oval tapered	crown broad, uneven
Trunk: straight, cylindrical and vertical	generally flexuous, rarely vertical
Branches: bases slightly pronounced	bases with very pronounced swelling
Shoots: thin, always cylindrical	thin, cylindrical, hairy at first
Leaves: (on long shoots) large, heart-shaped, tapering, with scattered erect hairs, slightly persistent;	fairly large, heart-shaped, downy, whitish at least at first
(on short shoots) suborbicular, glabrous, coarsely and irregularly toothed	glabrous, suborbicular, coarsely and irregularly toothed
Petiole: long, thin and flattened laterally	long, thin and flattened laterally
Buds: small, adpressed, shiny, stiff and pointed	small, adpressed, shiny, stiff and pointed
Bark: smooth, greenish-yellow, with few lenticels	yellowish-gray or greenish, with numerous large rhombic lenticels
Rhytidom: develops very late	develops early, rather deeply fissured

The selection of the best aspen clones, which is at present being undertaken in various countries (Denmark, France, the Netherlands, the United Kingdom, Sweden, etc.), is directed not only toward technological properties and speed of growth but also to easier methods of reproduction.

The following species may be linked with *Populus tremula*: *P. globosa* Dode, of the Lebanese Mountains, *P. adenopoda* Maxim., which is widely distributed in China, as well as *P. davidiana* Dode, *P. sieboldii* Miq. of Japan, etc.

POPULUS TREMULOIDES Michx. - Quaking aspen, Poplar

Distribution

Its area of distribution is from Alaska to Newfoundland in the north, stretching to south of the Great Lakes on the east of the Great Prairie, and on the west into the coastal ranges and Rocky Mountains as far as

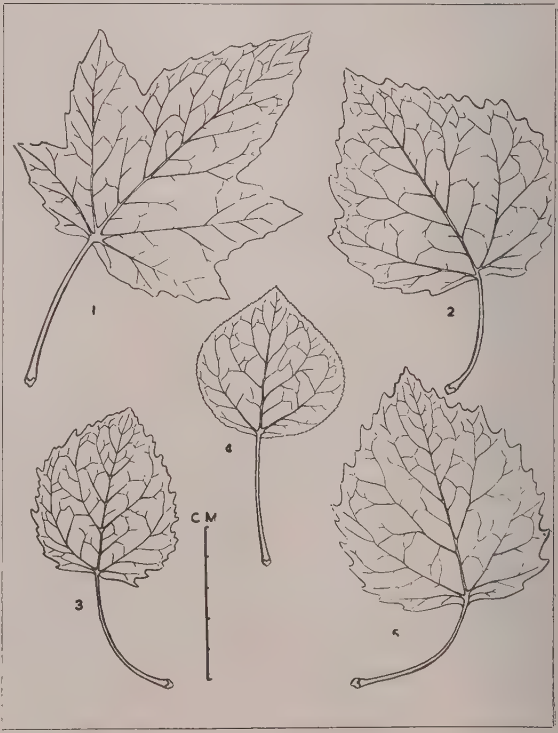


FIGURE 9. – Types of white poplar leaves.

A. Leaves of long shoots

1. *Populus alba*
2. *Populus* x *canescens*

B. Leaves of short shoots

3. *Populus tremula*
4. *Populus tremuloides*
5. *Populus grandidentata*

Mexico (trees in this western zone are sometimes related to var. *aurea Tidestr.* in the case of mountain types, and var. *vancouveriana* Trel. for coastal types).

Natural stands of *P. tremuloides* are of considerable economic importance in Canada and the United States, in particular to the Lake States.

Distinctive characters

Habit: varies from very slender and straight to little developed and flexuous.

Shoots: thin, cylindrical, smooth.

Leaves:

On long shoots: very large with glands at the base, smooth and firm with small regular toothing.

On short shoots: suborbicular, smooth, with small regular toothing.

Petiole: flattened laterally, the same length as the leaf blade.

Buds: shiny, slightly sticky.

Bark: smooth, creamy-white to greenish.

Rhytidom: late in developing, furrowed longitudinally.

Selection of the best clones has recently been undertaken, as for *P. tremula* in Europe.

POPULUS GRANDIDENTATA Michx. - Bigtooth aspen

Distribution

This species is confined to southeast Canada and the northeast of the United States of America, where its economic importance is fairly limited; for exploitation purposes this species is not distinguished from *P. tremuloides*.

Distinctive characters

Shoots: fairly strong, cylindrical, pubescent at first.

Leaves:

On long shoots: large, pubescent, with large regular toothing.

On short shoots: large, smooth, sinuate, with irregular toothing.

Petiole: compressed, shorter than the leaf blade.

Buds: dull, grayish, pubescent.

POPULUS TREMULA L. X *POPULUS TREMULOIDES* Michx.

For some years a hybrid of these two species has been cultivated in different countries, the growth of which is very rapid and superior to that of the parent species. Pollen sent by air from North America enables the large numbers of plants to be produced which are then established over a wide area, notably in Sweden.

White poplars, which are found only in Eurasia and in North Africa,[1] are grouped by botanists and dendrologists into a single large species, *Populus alba* L., which is described by its author as follows: " Foliis subrotundis, dentato-angulatis subtus tomentosis " (*Species plantarum*, Linné, 1753). This very vague description has enabled quite different and distinct forms, both morphologically and ecologically, to be linked with *P. alba*, thereby making it impossible in practice to interpret the descriptions of trees known by this single name.

The subsection *Albidae* Dode is divided into two groups or large species:

1. *POPULUS ALBA* L.

These are the true white poplars. The leaves are always white underneath, even those on short shoots. Heteromorphism (long-shoot leaves more or less lobed) is very marked.

Distribution and importance

River valleys of the western basin of the Mediterranean (France, Italy, Morocco, Spain), of central and eastern Europe, and of western and central Asia (the Balkans, Turkey, Turkestan, etc.).

These natural stands, while very useful to the rural economy of the regions in which they occur, are generally of little importance from the industrial and commercial point of view.

Distinctive characters

Habit: variable, crown generally full.

Trunk: more or less flexuous, sometimes very straight (varies from tree to tree).

Branches: very ramified, forming a dense crown.

Shoots: thin, cylindrical, downy.

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[1] Brandegee and Sargent have described a white poplar of northwest Mexico (in the Sierra de la Laguna, 600 to 1,500 meters, Lower California) - *P. monticola* Brandegee = *P. brandegeei* Schneid. - but very little is known of it and it may be of European origin.

Petiole: fairly short, flattened in the upper part only.

Leaves: undersurface always covered with a thickish more or less persistent white down.

On short shoots (the first to appear in the spring): always sinuate-toothed, varying in shape from narrowly elliptic to heart-shaped and suborbicular.

On long shoots (long summer shoots of seed, suckers and coppice shoots): leaves fairly large and nearly always deeply lobed.

Buds: small, subacute or obtuse, pubescent.

Bark: of grayish metallic color, later chalky white with large rhombic lenticels.

Rhytidom: develops late, deeply fissured.

Wood: a yellow line caused by a characteristic exudation appears on a section of the stem where heartwood and sapwood meet.

Ecology

The natural sites of white poplars growing in hot and generally dry regions are always associated with the presence of water; they are, nevertheless, fairly drought-resistant. They are extremely resistant to high temperatures, wind and a certain degree of salinity in the soil or water. Conversely, they are sometimes affected by winter frosts. They sucker very vigorously and considerably away (50 meters) from the parent tree, and seed abundantly in open places such as sandy banks.

Growth characteristics

They can be propagated fairly easily from cuttings, and hence the cultivation of several forms; but after felling the area is usually regenerated by coppice shoots, root suckers and seeds.

NATURAL VARIETIES

a) ***Populus alba*** **L. var.** ***nivea*** = ***P. nivea*** **Willd.**

This species group contains all the white poplars with palmate-lobed leaves on long shoots, many forms of which have been described by different specific or varietal names: *floccosa*, *comesiana*, *palmata*, *epirotica*, *peroneana*, *paletzkyana*, *martiana*, etc.

Distribution

Europe, from Spain to the Balkans and probably into western Asia as far as the Caucasus and Turkestan.[2] It is grown throughout the world as an ornamental tree.

Distinctive characters

The characters of this species are those of the group to which it belongs, except that the leaves on long shoots are always deeply lobed, the 3 or 5 (and even on occasion 7) lobes being more or less toothed. The petiole, which is truncate-straight or rounded at the base, is dark green in color and rather shiny (downy at first), the upper surface covered with a dense snowy tomentum, the undersurface felted. On the undersurface of short-shoot leaves, which are entire and elliptical, the tomentum is much less dense but is nevertheless always present and persistent, often with a silver sheen.

Ecology

This species is resistant to both cold and wind, as well as to a certain degree of soil salinity, and will even grow on fairly dry sites.

Growth characteristics

They generally propagate easily from cuttings and grow rapidly. The attention of those engaged in clonal selection is drawn to the fact that their habit is variable and often mediocre.

b) ***Populus alba*** **L. var.** ***subintegerrima*** **Lange**
Populus alba **L. var.** ***hickeliana*** **Dode**
Populus alba **L. var.** ***microphylla*** **Maire**

Distribution

The western basin of the Mediterranean in Italy, Sardinia, Spain, Algeria and Morocco: the respective localities of each variety are not precisely known.

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[2] Related forms of *P. nivea* Willd. which have lobes only slightly toothed, or not toothed at all, and which are associated with *P. triloba* Dode, exist in the western Himalayas.

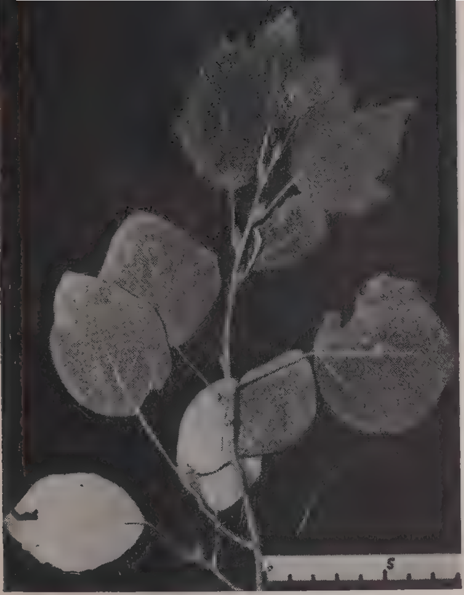

FIGURE 10. – Example of foliage polymorphism in a Moroccan white poplar.

Courtesy *J. Pourtet*

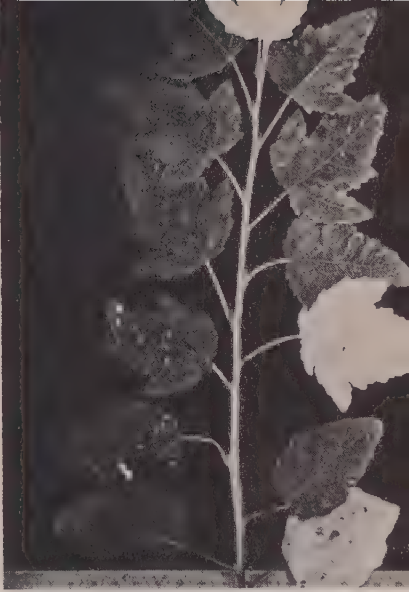

FIGURE 11. – *P. alba* var. *nivea* (Rhône Valley). At base, short-shoot leaves.

Courtesy *J. Pourtet*

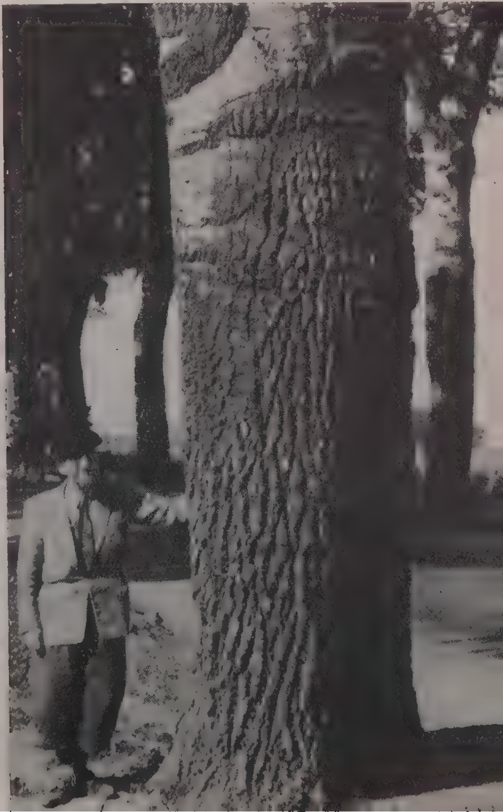

FIGURE 12. – *P. nivea* with a girth of 3 meters, near Coursan, France.

Courtesy *J. Pourtet*

Distinctive characters

The leaves are often small, leathery, never palmate-lobed, and very white beneath.

- Long-shoot leaves: elliptic, tapered, with an entire or toothed margin, and generally having 2 lateral lobes.
- Short-shoot leaves: small and elliptical in the case of *P. alba* var. *hickeliana*, larger and suborbicular in the case of var. *subintegerrima.*

Ecology

They are resistant to drought and even to an extremely dry atmosphere but are generally rather sensitive to winter frosts.

Growth characteristics

They propagate very easily from cuttings, their growth is rapid, and their habit is sometimes satisfactory.

CULTIVATED CLONES

Although *Populus alba* L. var. *nivea* has been reproduced throughout the world for ornamental purposes, no single cultivar, particularly notable for its beauty, form or rapidity of growth, has been described and commercialized.

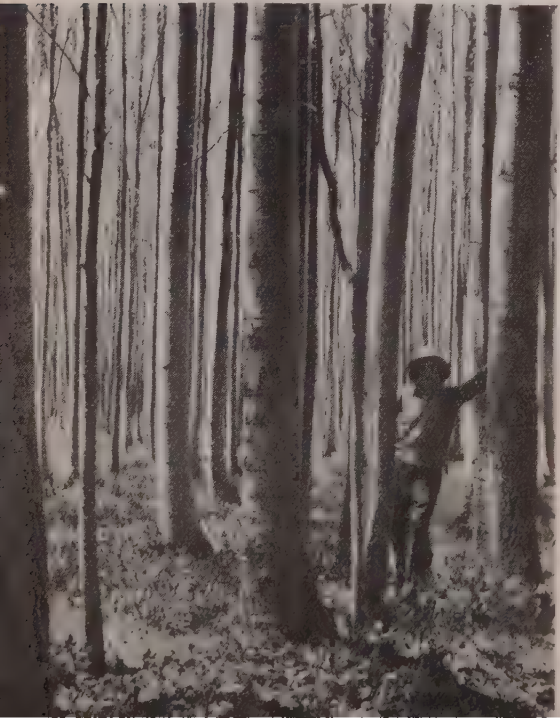

FIGURE 13. – Twice cutover coppice of *P.* ' bolleana ', aged 26 to 28 years, growing on rich alluvial soil near a watercourse. Tanail State Forest, Lebanon, Bekaa plain, altitude 900 meters.

Courtesy *de Tarade*

However, the following cultivar is grown in the Near East:

Populus alba L. cv. 'Roumi'

Distribution and importance

It is cultivated very extensively in Syria and to a certain extent in neighboring countries.

Distinctive characters

Habit: slender, semi-fastigiate.
Trunk: very straight.

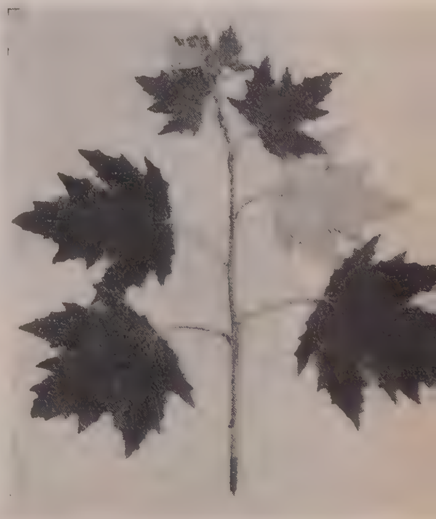

FIGURE 14. – *P. alba* cv. 'Roumi': upper and lower surfaces of its leaves.

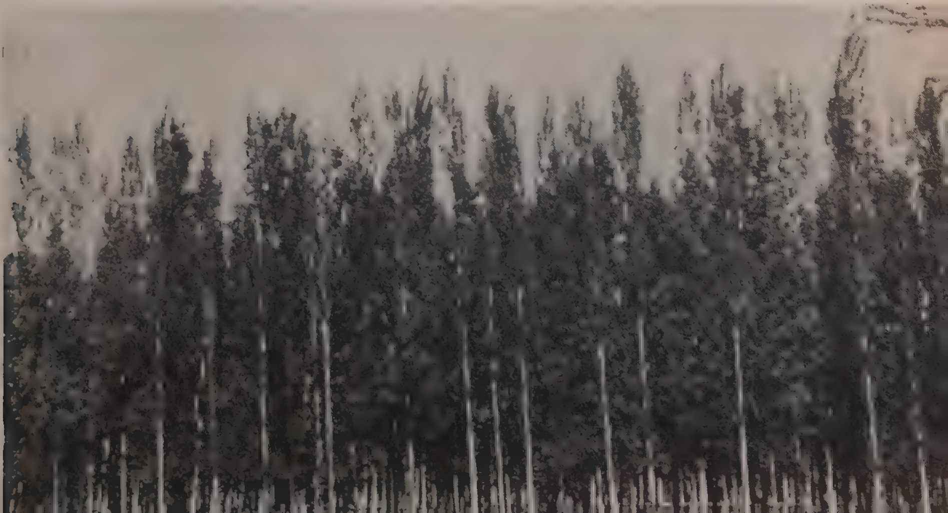

FIGURE 15. – Windbreak of 'Roumi' poplars, including a row of 'Hamoui' poplars, bordering an irrigation canal in the *ghouta* of Damascus.

Leaves: of the same shape as those of *P. alba* var. *nivea*, but the down of the undersurface is grayish, and that of short-shoot leaves very slightly persistent. The petioles are strongly flattened.

Sex: male.

Some of these features are perhaps typical of hybrids, and appear identical to those of the clone cultivated in western Europe for ornamental purposes under the name of *P. bolleana* Lauche.

Growth characteristics

Rooting from cuttings is fairly easy and enables dense stands to be raised and established which, after successive thinnings, are maintained to an age of 35 or 40 years.

2. *POPULUS CANESCENS* Sm. - Gray poplars

The poplars of this group are generally thought to be of hybrid origin; they derive from the crossing of *P. tremula* L. with *P. alba* L. var. *nivea* Willd. Hence they are also known by the name of *P.* x *canescens* Sm.

Distribution and importance

Gray poplars are found throughout Europe wherever the parent trees coexist (river basins of the Rhine, Rhône, Danube, Po, etc.), but they extend broadly to the northwest of the area at present occupied by *P. alba* var. *nivea*, where they hold their own and regenerate freely, mainly by vegetative means.

Distinctive characters

Habit: slender with full crown.

Trunk: attains large dimensions.

Leaves: there is little difference between short-shoot and long-shoot leaves, both are frequently suborbicular, sinuate and without lobes. The down of the undersurface is grayish and soon breaks down. The adult leaf resembles that of aspen but is larger and the petiole less compressed.

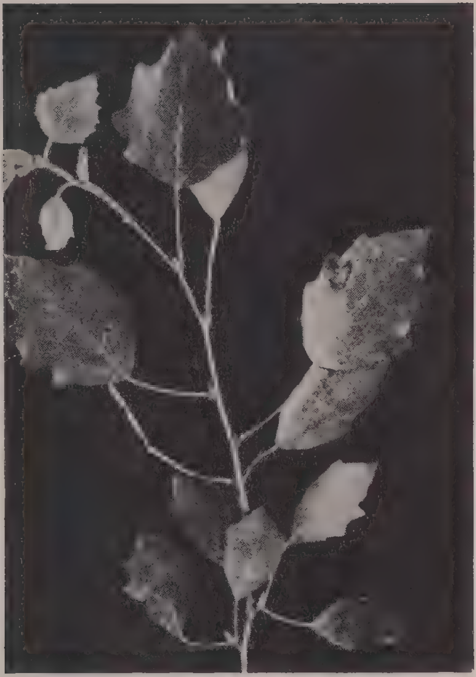

FIGURE 16. – *P.* x *canescens:* slight foliar dimorphism.

Courtesy *J. Pourtet*

Ecology

It is very adaptable and grows well in all types of soil, even when compact and peaty; it is fairly drought-resistant and less light-demanding than aspen.

Growth characteristics

The success of propagation from cuttings varies considerably from one clone to another, and is sometimes practically impossible. Suckering is very vigorous and alone is often sufficient to ensure reproduction.

Cultivated clones

Clones are often propagated in a limited region, for example:

***Populus* x *canescens* Sm. cv. ' megaleuce '**

Cultivated primarily in France (the Paris basin) under the names of White Poplar of Holland,[3] Franc-Picard, Ypréau, etc.

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[3] In spite of its name, this clone is unknown in the Netherlands.

Distinctive characters

Leaves: fairly large, those on long shoots sometimes lobed.
Sex: male.
Leafing: fairly late.

Growth characteristics

It suckers vigorously but cannot be rooted from cuttings.

***Populus* x *canescens* Sm. cv. ' bachofenii '**

Of very fine habit, roots easily from cuttings, and is differentiated and propagated in the Danube basin in Yugoslavia (sands of Deliblatsko).

C. SECTION *AIGEIROS* - Black poplars

Black poplars are not distributed as widely as poplars in the Section *Leuce*. They do not extend so far to the north (generally not reaching the 60th parallel), and are not grouped into a compact region of the Northern Hemisphere; they are divided rather into a Eurasian distribution and a North American distribution. In the first of these, *Populus nigra* is the only representative, while in the second, *Populus deltoides* is the most important.

With the introduction of the American poplar into Europe at the beginning of the eighteenth century, these two main species have given rise to a large number of hybrids; in many countries, particularly in western Europe, these hybrids have often virtually ousted the original species.

Ecology

The black poplars are light-demanding and cannot stand even slight oblique shade. They require a good damp soil, deep and fresh, preferably containing a little clay. Although they stand up very well to temporary flooding in winter, they are as a whole extremely sensitive to acid soils and to stagnant water. Black poplars are not at home in peat bogs. They are, however, typical constituents of groups of *Salicaceae* which are found principally in river valleys: as survivors on river banks in western Europe; on a larger scale in central and eastern Europe; and in vast plantations in the " bottomlands " along the large rivers in the east of North America. They have been propagated very extensively on soils with a profile and especially with a water regime similar to the association

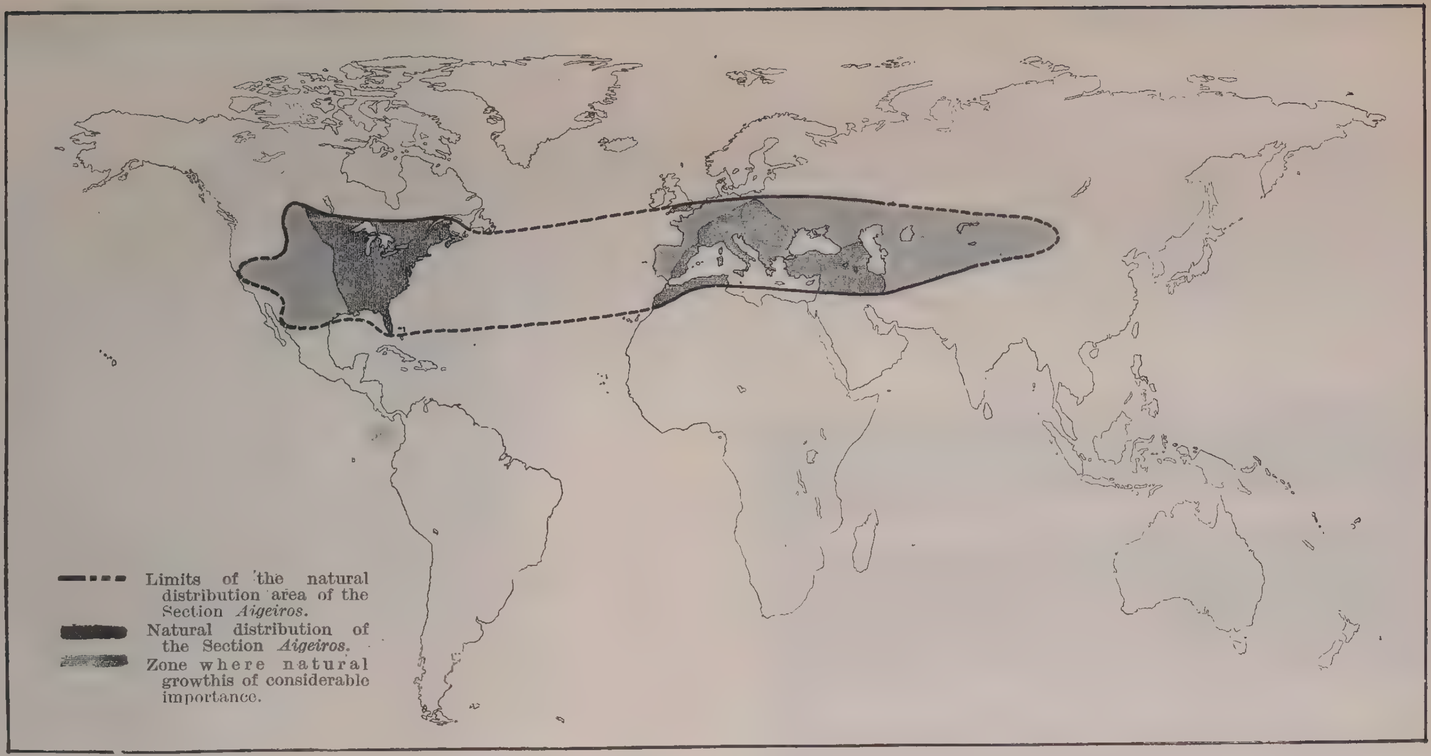

Limits of the natural distribution area of the Section *Aigeiros*.
Natural distribution of the Section *Aigeiros*.
Zone where natural growthis of considerable importance.

FIGURE 17. – World distribution of black poplars (Section *Aigeiros*)

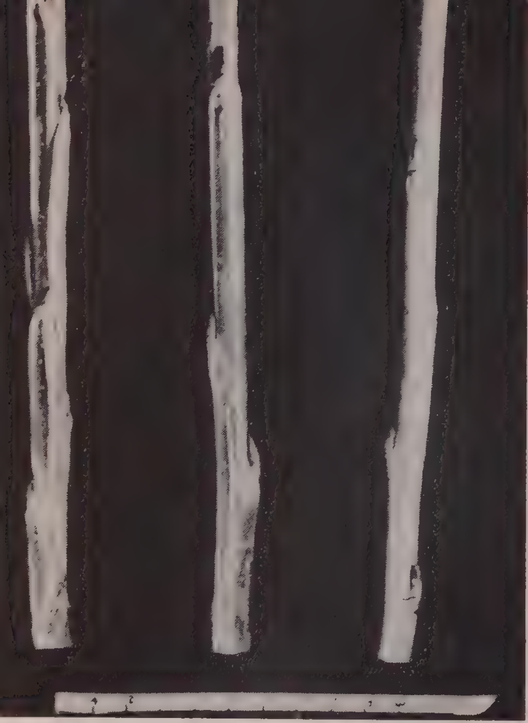
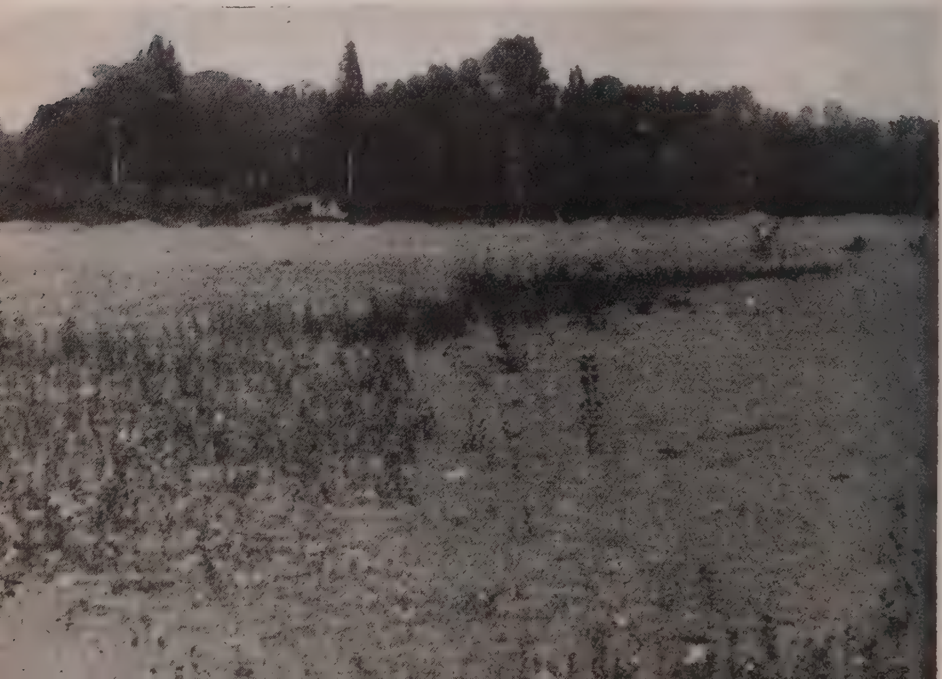


FIGURE 18. – Vigorous shoots of black poplars. Left to right: *P. deltoides* ssp. *angulata*, *P.* x *euramericana* 'robusta' and *P. nigra*.

Courtesy *J. Pourtet*

FIGURE 19. – Natural seeding of *P. nigra* L. (black poplar) indigenous to the Loire Valley, France.

Courtesy *R. Régnier*



described above. In their natural habitat, together with willows, they are the ideal pioneer species for new sites, where they are readily established owing to their light seed, which can be carried great distances, and to their rapid growth. However, owing to their great need for light, they do not stand up well to competition from other trees and are easily eliminated by them later. All black poplars reproduce themselves vegetatively, either easily or very easily. The usual method is to plant one-year-old stem cuttings in a nursery. Propagation by seed is only used in selection work. Because of their generally shallow root system, they may be subject to windblow, although the roots are capable of changing and can adapt themselves to the particular soil conditions. Black poplars are, therefore, fairly resistant to wind, which has little effect on their growth on open lands where few other species would be able to exist.

Systematic botany

The *Aigeiros* section is divided into two groups:

1. Young round shoots without ribs; nonciliate leaf margin.
2. Young shoots at first rather angled, sometimes with straight longitudinal ribs; ciliate leaf margin.

Eurasian poplars belong to the first group and American poplars to the second.

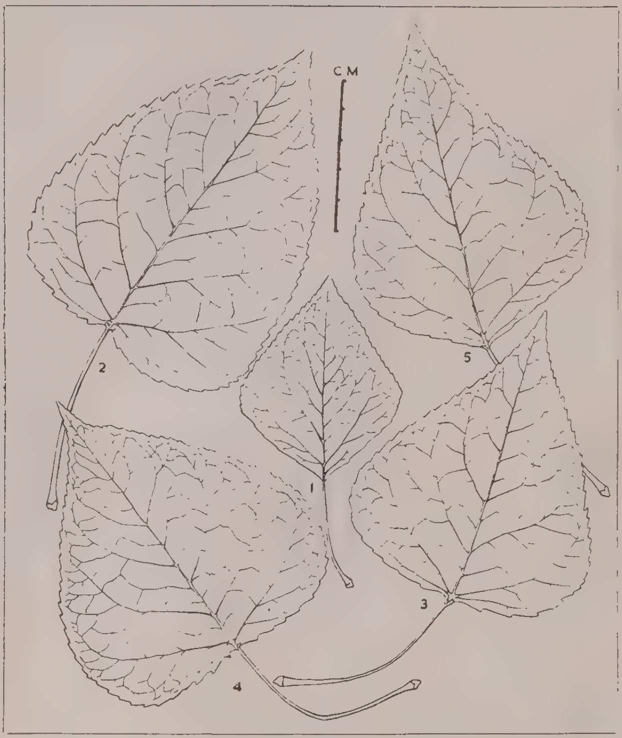
Euramerican hybrids do not normally have a ciliate leaf margin but the young shoots are more or less angled.

POPULUS NIGRA L.

Distribution and importance

The only representative of this group of Eurasian poplars, this important species has a very extensive yet compact distribution in the southern third of Europe from the Danube to the Mediterranean, and in Asia Minor, extending as far as central Asia where, however, its limits are not precisely known. It extends northward into the valleys of the principal rivers, the Rhône, Elbe, Oder, etc. Isolated sites occur in North Africa (the mountains of Algeria and Morocco) and probably also in England.

Natural mixed stands of *Populus nigra* growing in mixture with white poplars, willows and alders, are only of economic importance in the large valleys of southern Europe and western Asia. Only clones selected and cultivated artificially in certain regions are of importance for timber



1. *Populus nigra*

2. *Populus deltoides* ' angulata '

3. *Populus deltoides* ' missouriensis '

4. *Populus* x *euramericana* ' serotina '

5. *Populus* x *euramericana* 'marilandica'

FIGURE 20. – Types of black poplar leaves.

production and in the protection of farm crops with which they are associated (for example, the Mediterranean peninsulas and in particular the Near East).

Distinctive characters

Habit: variable.

Trunk: often flexuous and rather short, marred by burrs.

Crown: strong, very ramified branches with a large number of short shoots forming a very dense crown.

Shoots: cylindrical and fairly slender; very vigorous shoots can be somewhat angled but are never ribbed longitudinally.

Buds: small, pointed.

Leaves: not very heterogeneous, always firm, dark green in color.

On short shoots: small, more or less rhombic.

On long shoots: do not exceed 6 to 10 centimeters in length, subdeltoid, rhombic, sometimes with faintly marked glands.

Petiole: long, thin, laterally compressed.

Inflorescences: female flowers have 2 stigmas arranged in short dense clusters (13 centimeters or less in length when mature); globular capsules open into 2 hemispherical valves. Male flowers have 6 to 30 purple stamens grouped in short catkins (4 to 6 centimeters).

Rhytidom: generally develops early and is very coarse, sometimes with large black swellings. In the crown the bark is yellowish-white.

Ecology

Populus nigra is adaptable and can grow in relatively poor, dry soils in which *P. deltoides*, for example, would not be able to exist. It is also adaptable from the point of view of temperature.

Reproduction and growth characteristics

P. nigra seeds abundantly on wastelands and on the banks of large and small rivers, sprouts vigorously after felling but only suckers in exceptional circumstances (on superficial, damaged roots). Artificially, it can be rooted easily from cuttings.

NATURAL VARIETIES

Numerous authors have raised to the status of varieties, or even species, forms of *Populus nigra*, which if reproduced vegetatively, would only be "clones." However, a variety which is often described deserves special mention: it is *Populus nigra* L. var. *betulifolia* Torr., which is distinguished from *P. nigra* type (var. *typica* Schneid.) by its pubescent shoots and young leaves. But since all populations of *P. nigra* appear to contain individual trees possessing pubescent young shoots, its distinction as a variety is not in fact justified on this account. It is mentioned as being peculiar to England and France.

On the other hand, in southern Italy two other very individual forms should be noted: *Populus nigra* L. var. *Caudina* Tenore, whose shoots and young leaves are definitely downy. Growth from long shoots is somewhat angled; young growth is slightly more reddish than in the case of *P. nigra*, and the leaves of these relatively large shoots are almost heart-shaped. The tree normally has a fairly straight habit.

P. nigra L. var. *neapolitana* Tenore is less erect, less hairy, its young shoots are almost green, and its leaves possess longer points.

Lastly, *P. nigra* L. var. *sinensis* Carr., which was probably introduced from China, is characterized by its yellow branches. It appears to be a vigorous, fast-growing tree.

CULTIVATED CLONES

Many of these clones are only of very limited local importance and are derived from the reproduction of individual trees selected empirically for their qualities within a local population. Several have been named but it is sufficient to mention here the types which deserve to be retained because of their growth characteristics, timber qualities and above all for their economic importance. It is worth noting that they are all more or less fastigiate.

Populus nigra L. cv. 'italica'

Distribution

This variety was probably introduced into Italy from the East in the remote past, and distributed widely throughout Europe in line plantings and for timber production; it later spread throughout the world as an ornamental tree, and from the eighteenth century onward was planted for protective purposes.

On account of its extensive distribution it was chosen by the International Poplar Commission as a standard clone for phenological studies. Although cultivation of this clone is decreasing everywhere, it is nevertheless important for artificial hybridizations.

Distinctive characters

Habit: strictly fastigiate.

Trunk: perfectly straight and vertical but with marked fluting or buttresses at the base forming a root swelling.

Rhytidom: develops early and is deeply fissured longitudinally.

Shoots: cylindrical, glabrous, light brown in color, and ramified at a very sharp angle.

Sex: male, flowers with 20 to 30 stamens grouped in catkins which appear early and soon fall; they are situated mainly in the upper part of the tree.

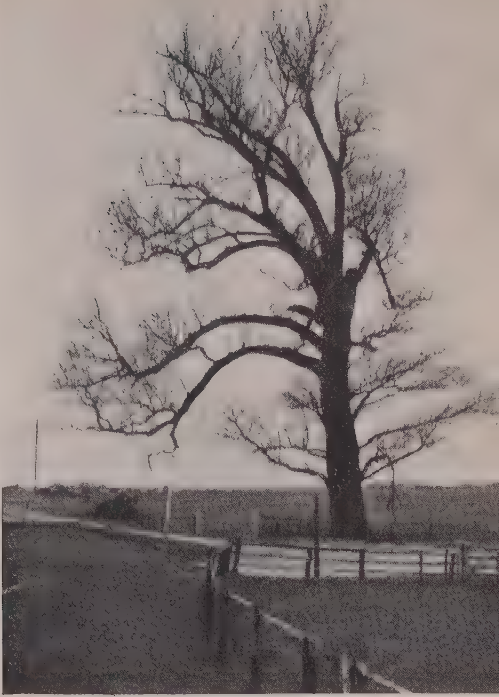


FIGURE 21. – Old specimen of European black poplar (*P. nigra*).

Courtesy *Nederlandse Heidemaatschappij*

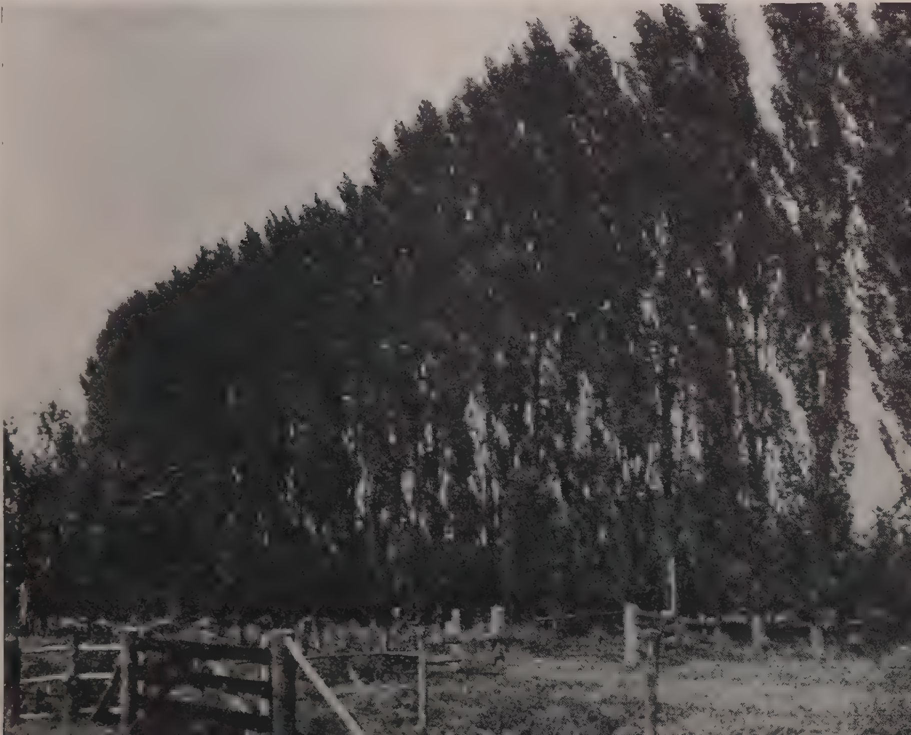


FIGURE 22. – An orchard protected by a windbreak of *P. nigra* ' italica '.

Courtesy *G. Houtzagers*

Leaves: small and fairly firm.

On short shoots: strongly rhombic.

On long shoots: rhombic, triangular, broad with a sharp point.

Ecology

This clone is so adaptable that it can be planted in a very wide range of climate and soil.

Dieback and even death of the crown caused by a *Nectria* fungus is frequently reported.

Reproduction and growth characteristics

The Italian poplar roots extremely easily from cuttings and grows very rapidly when young. It can attain very large dimensions (several meters in circumference and more than 30 meters in height). It is ideally suited to line plantings, particularly because its crown does not spread and it is quite unaffected by phototropism.

***Populus nigra* L. cv. ' Hamoui '**

Distribution

The exact origin of this clone is not known but it was probably in central Asia. Cultivated from remote times and on a large scale in the Near East, particularly in Syria and the Lebanon, it spread to most of the regions which came under the domination of Islam, namely Cyprus, North Africa (=*Pop...* = *Populus thevestina* Dode) and in particular south of the Balkans (Jablan in Yugoslavia) where, as in the Near East, its cultivation is of considerable economic importance. In Syria, it is cultivated over tens of thousands of hectares and produces annually more than 100,000 cubic meters of wood.

Distinctive characters

Habit: very strictly fastigiate.

Trunk: straight, vertical and always perfectly cylindrical.

Rhytidom: very late in developing. The bark remains smooth and white for a very long time.

Shoots: cylindrical, light silver-gray in color.

Sex: female, catkins occur in short dense clusters.

Leaves: small; elliptic-ovate on short shoots.

Ecology

Cultivated in the Mediterranean area, this clone is generally associated with the presence of water, although it appears capable of tolerating a certain degree of dryness. It is in fact remarkably well adapted to dry climates of the "continental" type but does not seem to do well near the sea. It can stand fairly low winter temperatures, and young trees have not been damaged in east France at a temperature of –19° C.

It is rooted very easily from cuttings, and especially from sets cut from the crowns of neighboring trees and planted direct.

Its growth is very rapid but this is soon slowed down due to the very dense nature of the stands resulting from the general use of close spacings, the trees consequently never reaching a very large size. However, they grow remarkably well under these crowded conditions, without premature dieback and without phototropic deformation.

Populus nigra L. cv. ' Farsi '

This poplar, which is reported from Syria, is probably fairly closely related to the ' Hamoui ' variety but with a less erect habit and a slightly flexuous bole. The trees observed were male. It is grown for fuelwood.

Populus nigra L. cv. ' Vert de Garonne '

Distribution and importance

This group of clones, selected empirically in France in the basins of the Rhône and particularly of the Garonne, is grown extensively in these areas, where it plays a fairly important role in the rural economy. They are apt to be ousted by more productive poplars. Their foliage is used for cattle.

Distinctive characters

Habit: erect, but much less strictly fastigiate than the preceding clones.
Trunk: straight and fairly cylindrical.
Rhytidom: develops quite early.
Sex: most of the clones are female.

Ecology

Fairly demanding as to moisture and heat.

Growth characteristics

It can be rooted easily from cuttings.

Populus nigra **L. cv. ' Bordils '**
Populus nigra **L. cv. ' Poncella '**
Populus nigra **L. cv. ' Blanquillo de Granada '**

These and several other less important poplars are widely cultivated in Spain, the first two in Catalonia and the third in Andalusia. A detailed description of these varieties and comparison with the classic types described above, particularly with *P. nigra* ' italica ', are as yet incomplete. It is difficult therefore to give precise information as to their sex, date of leafing, etc. They appear, however, to come into leaf relatively early and, without having as fast a growth rate or producing as good a quality timber as the Euramerican poplars, they undeniably have a value.

They are characterized, like all poplars of the *nigra* group, by small leaves, dense crowns and abundant epicormic shoots which sprout from the trunk even in the most crowded stands.

POPULUS DELTOIDES Marsh. - Eastern cottonwood

Distribution and importance

In North America *Populus deltoides* has an importance comparable with that of *P. nigra* in Eurasia. Its natural distribution extends from the Atlantic on the east as far as the Great Plains, and from the Great Lakes to the Gulf of Mexico.

In natural forests it is found chiefly on alluvium — the so-called " bottomlands " — along the great rivers Mississippi, Ohio, Missouri and their tributaries, where it is a pioneer species in mixture with *Salix*. It is, however, gradually replaced, without human intervention, by a large number of other broadleaved species (*Platanus*, *Diospyros*, *Carya*, *Liquidambar*, *Gleditsia*, *Nyssa*, *Ulmus*, *Quercus* *Acer* and others).

Most stands of *P. deltoides* are formed even today by natural seeding on the recent alluvial deposits of the great American rivers. As seeding on these fresh soils is very dense, only very rigorous selection at an early age allows the most vigorous and fast-growing of the young plants to survive.

This species can be very easily rooted from cuttings with only occasional difficulty in the case of ssp. *angulata*.

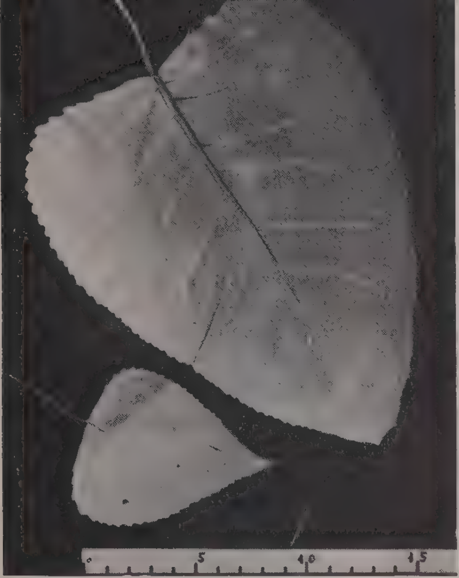


FIGURE 23. – *P. deltoides* cv. ‘ carolinensis ’. Leaf of long shoot (very large) and leaf of short shoot.

Courtesy *J. Pourtet*

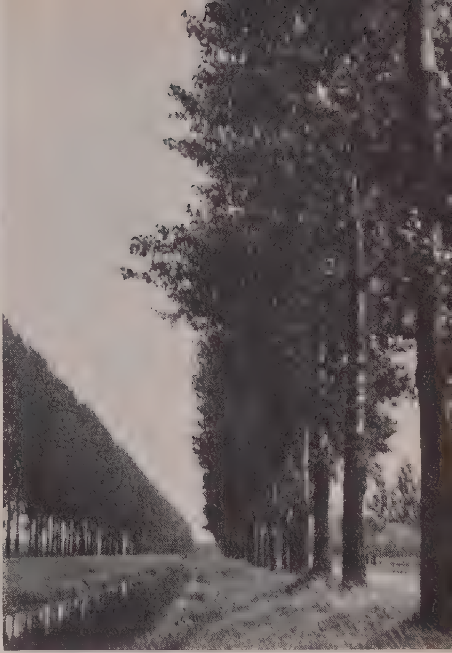


FIGURE 24. – Plantation of *P. deltoides* cv. ‘ missouriensis ’ Dutch importation.

Courtesy *G. Houtzagers*

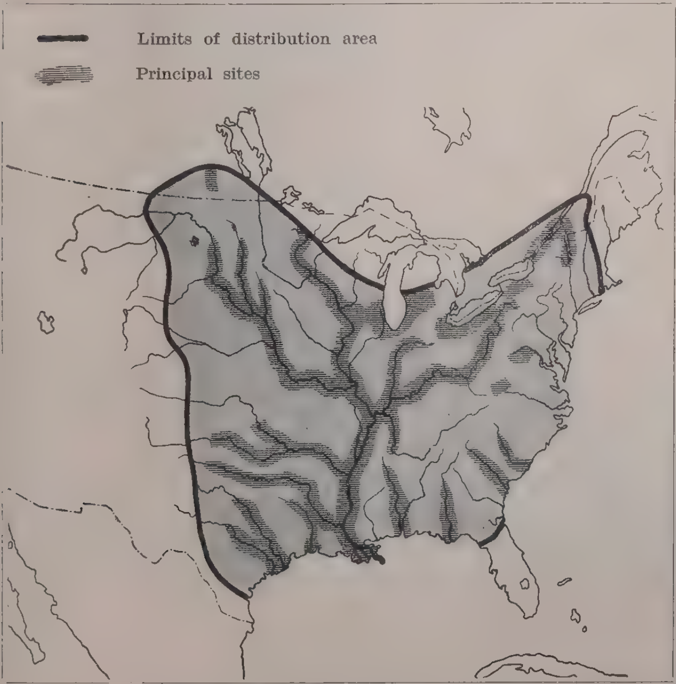

Limits of distribution area
Principal sites

FIGURE 25. – *Populus deltoides* Marsh.

FIGURE 26. – *P. deltoides* cv. ‘ angulata de Chautagne ’. Suberous ribs on the bark of a young tree.

Courtesy *R. Rol*

NATURAL VARIETIES

On account of its vast natural distribution this species can be divided into three subspecies:

- ssp. *angulata* Ait., essentially a southern strain, although an isolated pocket of its natural distribution occurs in New England;
- ssp. *missouriensis* Henry, found in a relatively small central section of the distribution area (Tennessee, Missouri);
- ssp. *monilifera* Henry, in the northern part of the area (Dakota, Wisconsin, Minnesota, Michigan).

Distinctive characters

These three subspecies usually have a straight trunk (especially ssp. *missouriensis*) and their young shoots have long lenticels (*P. nigra* has round lenticels only). The leaves are considerably larger and more definitely triangular in shape than those of *P. nigra* and always have two glands at the junction of the petiole and leaf blade.

Buds: brownish, often slightly viscid.

Male catkins: 7 to 12 centimeters long with 40 to 60 stamens and 3 to 4 stigmas.

Female catkins: 15 to 25 centimeters long when mature; the capsule has a short stalk and opens into 3 to 4 valves.

ssp. *angulata* has larger leaves, fairly broad in the upper part, or "shouldered;" the shoots are strongly angled and possess ribs which become suberous; similar ribs are also visible on the large branches and on the upper part of the trunk. Short shoots are rare and thus old trees with spreading habit have a broad crown, which gives the impression that it is not very dense (rather like red oak as compared with pedunculate oak). The rhytidom develops fairly early.

Leafing generally occurs early (before the Italian poplar). This tree is sensitive to low temperatures and consequently its extension northward is limited by its heat requirements, with the exception perhaps of the New England strain. It prefers moist sites.

ssp. *missouriensis* has slightly smaller leaves, longer than they are broad, straight or shallowly heart-shaped at the base, long-pointed at the apex, dark green in color and shiny. This subspecies has more short shoots than *angulata* and consequently has a denser crown. The shoots are not as angled as those of *angulata*, and old shoots do not possess suberous ribs. The lower branches of old trees are often slightly drooping. The tree has a fairly erect habit, normally with a very straight trunk — straighter than *angulata* and *monilifera*. The rhytidom is black and develops relatively early. Leafing usually occurs a bit later than in the case of *P. angulata*.

ssp. *monilifera* has the smallest leaves of the three subspecies. They are as broad — or broader — than they are long, often shallowly heart-shaped at the base or even slightly wedge-shaped along the petiole, lighter in color and less leathery than the preceding subspecies, and very coarsely toothed. Date of leafing is the latest of the three subspecies. The trunk is often slightly flexuous. The crown is fairly broad (semi-spreading) and rather loose. The bark is light in color with blackish ribs, the rhytidom coarse and darker in color. This is a more adaptable form of *Populus deltoides*, growing even on sandy soils and generally having a very rapid rate of growth.

Cultivated clones

Various imported clones of this important American species are grown in western Europe, and sometimes in Asia, Mediterranean Africa and South America. Their exact origin is not known.

1. Associated with ssp. *angulata:*

***Populus deltoides* cv. ‘ carolinensis ’ or ‘ Carolin ’**

Male clone which can be reproduced with difficulty from cuttings, is very demanding as to moisture and heat. It requires a long growing season (Valley of the Garonne, France, Morocco, Lebanon, etc.).

***Populus deltoides* cv. ‘ Caroliniano di Cercenasco ’**

Female clone with a very white trunk, cultivated in Italy.

***Populus deltoides* cv. ‘ angulata de Chautagne ’**

Female clone cultivated in the southeast of France, less sensitive to low temperatures than the two preceding clones and relatively easy to propagate from cuttings.

2. Associated with ssp. *missouriensis:*

Populus deltoides cv. ' missouriensis Dutch importation '

Male clone imported into the Netherlands in 1891 by the *Nederlandsche Heidemaatschappij.* It is unlikely that it was introduced into Europe before this date. With its erect habit and straight trunk it is very valuable in line plantings and has proved itself resistant to sea winds in the Netherlands. It grows as well in clay as in sandy or even slightly peaty soils, and prefers a low to a high water table. Leafing takes place at approximately the same time as *P. nigra* ' italica ' and before *P.* ' robusta '.

3. Associated with ssp. *monilifera:*

Populus deltoides cv. ' monilifera '

An early flushing male clone, sometimes cultivated in the north of France.

Populus deltoides cv. ' virginiana '

Necklace poplar, *Rosenkranzpappel,* is a group of several female clones characterized by very long female catkins; they may perhaps be crossed with *P. nigra* (the capsules open generally into 2 valves, rarely 3, and never into 4). Very widely grown in France and in scattered plantations elsewhere in Europe, they have a very rapid growth rate in good fresh soil but have a mediocre habit. They produce considerable " cotton " which is sometimes troublesome.

Other American species whose importance is much less than that of *P. deltoides* but which nevertheless deserve mention are:

POPULUS SARGENTII Dode

Distribution

Alberta and Saskatchewan in Canada to Nebraska, western Texas and New Mexico in the United States.

This is a smaller tree than *P. deltoides* and its young shoots are lighter and more yellowish in color, the lenticels are similarly narrow, long and white.

Buds: fairly short, obtuse, adjacent and sometimes slightly pubescent.

Leaves: smaller than those of *P. deltoides* (7 to 10 centimeters,) yellowish-green, very coarsely toothed, often broader than they are long.

POPULUS FREMONTII Wats.

Distribution

Sierra Nevada (California, Nevada, as far as North Arizona).

Leaves: light green, kidney-shaped and then sometimes wedge-shaped, tapering into the petiole; in old trees the leaves are often more or less rhombic.

Habit: spreading crown but fairly straight trunk.

Buds, shoots and leaves: glabrous.

Inflorescence: 3 to 4 stigmas; fruit has 3 to 4 valves; large number of dark red stamens (up to 60 in a single flower).

Considered by many authors to be a variety of the preceding species.

POPULUS WISLIZENII Sarg.

Distribution

West Texas and New Mexico.

One-year-old shoots are of a slightly darker color and the fruit have longer stalks.

POPULUS X *EURAMERICANA* (Dode) Guinier

The various hybrids between *P. nigra* and *P. deltoides* are easily the most important for cultivation - more important in fact than the parent trees.

Populus deltoides, or strictly speaking, its subspecies *P. deltoides monilifera* and *angulata*, was introduced into Europe toward 1700, while the introduction of the third subspecies, *missouriensis*, dates from 1891 (the Netherlands). Hybridizations — partly spontaneous, partly artificial — between these two species have given rise to a very large number of European poplars of economic importance not only to western Europe but also to many other countries in temperate zones throughout the world. These are added to annually by artificial crossings done in different countries, making it increasingly difficult to give sufficiently precise descriptions to distinguish between all the forms. In fact, the botanical differences are often too slight to permit separation and other criteria are therefore necessary. Sometimes the date of leafing in the spring, or the determination of the sex (the greater part are clones, or originally a small group of clones, and can only be propagated vegetatively) can yield valuable information. Sometimes forms which closely resemble each other have a totally different economic importance. For example, in the Netherlands *P.* 'gelrica' is very valuable and *P.* 'brabantica' worthless on account of its susceptibility to weeping canker, but it is very difficult to distinguish between these two trees when young.

Therefore, with the increasing number of new forms, the necessity for good varietal control is becoming more and more urgent. One can even go so far as to say that the desirable spread of poplar cultivation as a whole is impossible without such control in each country. The principles of varietal control will be discussed at the end of this chapter.

The nomenclature of this large group of hybrids *Populus nigra* x *P. deltoides* F_1 F_2 F_3, etc., has always given rise to considerable difficulties and, unfortunately, even today is not entirely settled. In practice they are often grouped, and hence more often confused, under the name of "Canadian poplars" and in literature are known by the name of *P. canadensis* Mönch.

In *Het Geslacht Populus*, G. Houtzagers,..... one of the editors of the chapter in question, discusses in detail the historical development of the nomenclature of this group of poplars, and shows that the name *P. canadensis* Mönch. *could* be accepted as a collective name for all the representatives of this group of hybrids according to the official rules of nomenclature. But he also shows that in forest literature since 1785, when Mönch described his *P. canadensis*, up to the present time, this name has caused much confusion; in practice also it has been applied by many authors sometimes to a purely American species, and sometimes to any hybrid which it was proposed to discard as a *nomen ambiguum* according to Article 62 of the International Rules of Nomenclature. For this reason the International Poplar Commission decided to reject the name of *P.* x *canadensis* and to introduce for the whole of this group the collective name *P.* x *euramericana* (Dode) Guinier, which includes all the hybrids of Euramerican origin.

This new name was proposed in 1950, with a Latin description, by the chairman of the International Poplar Commission at the International Botanical Congress at Stockholm.

To avoid any possible confusion, it was later agreed to retain the existing names of old hybrids which, in many cases, had been cultivated for more than 150 years and were known by such names as *serotina, marilandica, gelrica, robusta, regenerata,* etc.

This decision conforms to the rules of the international code of nomenclature for cultivated plants, which was accepted by the 13th International Horticultural Congress, held in London in September 1952. However, it is recommended that such varietal names (known as "cultivars") should be distinguished typographically from the Latin names used to denote botanical varieties, by using single inverted commas instead of italics. Hence, the official name of these old hybrids will be: P. x *euramericana* (Dode) Guinier cv. (= cultivar) 'serotina', 'marilandica', 'gelrica', etc. In practice they remain as P. 'serotina', P. 'marilandica', etc.

On the other hand, as a result of work on scientific hybridization, since new hybrids are constantly being created, all these new forms may be provisionally assigned a number preceded by the letters recognized internationally as representing their country of origin, much in the same way as for motor cars: for example, P. x *euramericana* cv. 'I-214' for Professor Piccarolo's already well-known Italian hybrid; or P. x *euramericana* cv. 'N.L. 60' (or P. x *euramericana* 'N.L. 60') for any hybrid from the Netherlands. Later, when such hybrids have proved of lasting value to poplar cultivation, this designation may be replaced by a "fanciful" name. This "fanciful" name cannot be Latin and must begin with a capital letter (for example, P. x *euramericana* [Dode] Guinier 'Glory of Italy').

With the introduction of this nomenclature the International Poplar Commission hopes to have put an end to all confusion, and has expressed the hope that botanists of all countries will also adopt it for their flora. In this way alone can the confusion which has existed for almost two centuries be ended.

Distinctive characters

Leaves: the leaves are generally larger than those of P. *nigra*, approximating those of P. *deltoides missouriensis* and *monilifera*. Their shape is a very important factor in determining the members of this group of hybrids, and it is necessary to emphasize once again the enormous variety of leaf shapes which may occur on a single tree. This heteromorphism, according to the kind of branch and its vigor, has already misled many poplar experts. In order to give a correct identification on the basis of the leaves it is necessary first of all to exclude all abnormal leaves, such as those of young nursery stock, epicormic shoots, coppice shoots, etc. Secondly, a distinction must be made between short-shoot leaves (brachyplasts) and long-shoot leaves (lamproplasts, auxiplasts or turions). The best leaves for the purpose of identification are adult leaves taken from the middle of long shoots. Thus the principal leaf shapes distinguished among Euramerican poplars are as shown in Figure 27.

A second important character used in the identification of members of this group is the reddish or greenish color of shoots before they reach maturity and of leafstalks, but here again it is necessary to take comparable shoots and leaves because the sun, and also the quality of the soil, may have a very strong influence on the color.

A third very important character — perhaps the most important — is the date of coming into leaf,[4] the color of the young leaves, and the date of flowering. Spring is therefore the most suitable time for identifying the different hybrids.

Finally, the following points should be borne in mind: the sex (male or female clone), the date of leaf fall in the autumn, the autumn color of the leaves, the habit (spreading or fastigiate), the shape of the trunk (straight or fexuous), the color of the bark, the color and thickness of the rhytidom, etc. (*see* example of a poplar identification form, Appendix 5).

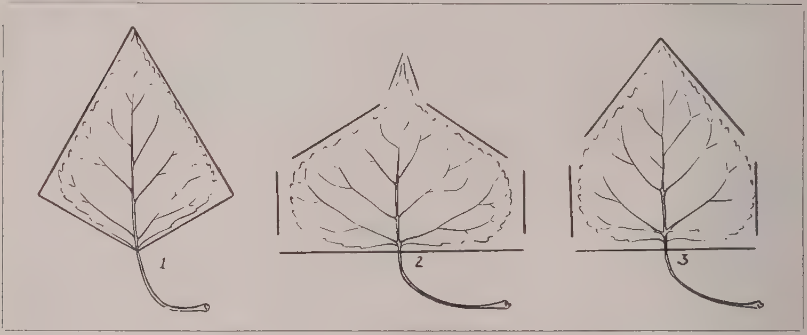


FIGURE 27. – Principal leafs shapes of black poplars.

In this way it is possible to split up Euramerican hybrids at least into groups, by endeavoring to find the distinctive characters of each type.

A brief description is given below of some Euramerican hybrids of international importance. They are all extremely easy to propagate vegetatively.

POPULUS X *EURAMERICANA* (Dode) Guinier cv. ' serotina '

This, the oldest of the Euramerican poplars, is a male clone characterized by very late leafing, a straight leaf base, nonwoody petiole and shoots of a deep reddish color. It is cultivated extensively in western Europe and grows well in clay and compact soils. It is strongly resistant to sea winds and to canker but during its early years is susceptible to *Dothichiza*. It is very long-lived.

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[4] In order to establish more easily the respective dates of leafing of various clones before the normal flushing period, Dr. Marcet experimented in Switzerland with a forced " water culture " of cuttings under glass, and obtained the complete foliation of *P.* x *euramericana* ' regenerata 04-6 ' in 30.8 days, and of *P.* x *euramericana* ' serotina 06-1 ' in 35.5 days.

The clone known in Switzerland as Peuplier d'Yvonand (Yvonand poplar) deserves mention.

POPULUS X *EURAMERICANA* (Dode) Guinier cv. 'serotina de Sélys'

This male clone was planted in 1818 at Waremme, to the west of Liège, after being raised in a nursery at Bernissem. With its very fastigiate habit it resembles Italian poplar, from which it is distinguishable by its rounder and more regular trunk, angled shoots and leaves which are larger than, but of the same shape as, 'serotina'; like the latter it also comes into leaf late. It is suitable for shelterbelts and roadside planting.

POPULUS X *EURAMERICANA* (Dode) Guinier cv. 'serotina erecta'
POPULUS X *EURAMERICANA* (Dode) Guinier cv. 'Bleu d'Exaerde'
POPULUS X *EURAMERICANA* (Dode) Guinier cv. 'serotina de Champagne'
POPULUS X *EURAMERICANA* (Dode) Guinier cv. 'serotina du Poitou'

Male hybrids, perhaps a crossing of 'regenerata' and 'serotina', are grown particularly in France, Belgium and the Netherlands; they are characterized by coming into leaf about one week before *P.* 'serotina' and by similar leaves; petioles and young shoots are only very slightly reddish in color, often appearing completely green. These hybrids are generally very resistant to sea winds and grow on clay and marshy soils. They are also canker-resistant. 'Bleu d'Exaerde' is a Belgian hybrid; 'serotina de Champagne' is cultivated in France (in the Aube, etc.); 'serotina du Poitou' grows in the coastal district between the Vendée and the Gironde and is fairly moisture-demanding and sensitive to cold but has a very rapid growth rate.

POPULUS X *EURAMERICANA* (Dode) Guinier cv. 'marilandica'

This female hybrid is grown extensively in the Netherlands and also in England. It has light green leaves, wedge-shaped at the base and longer than those of the previous hybrids; petioles and young shoots are green. Female catkins are long (approximately 20 centimeters when mature). Leafing occurs from two to three weeks before *P.* 'serotina'. The tree has a spreading habit and the trunk is often flexuous.

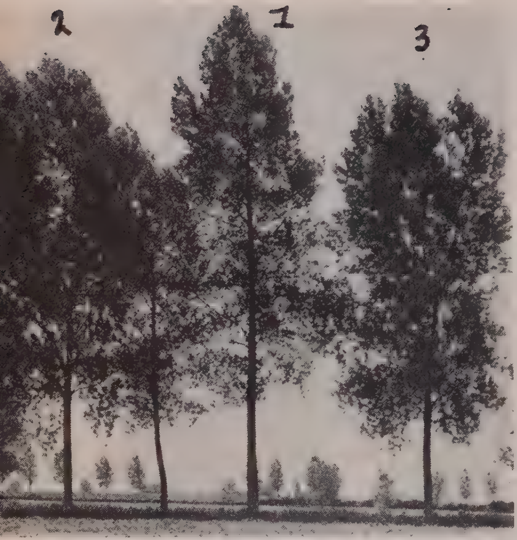


FIGURE 28 *a*). – *P.* 'eugenei' (1) and *P.* 'robusta' (2 and 3) at Ryston Hall, England.

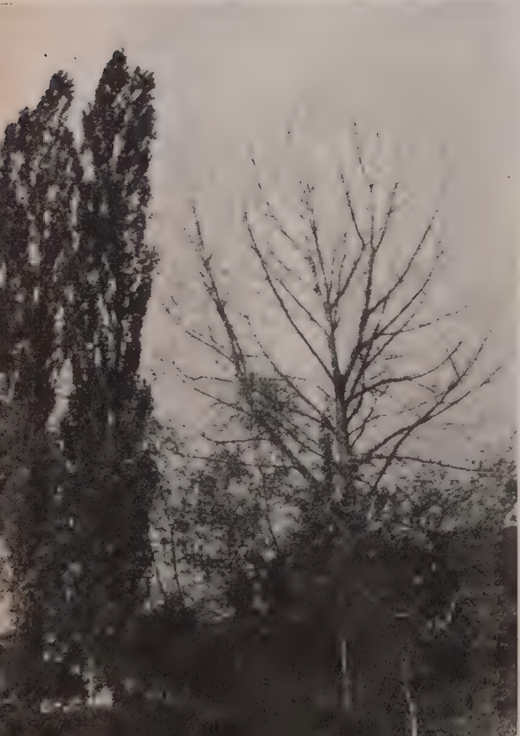
Courtesy *G. Houtzagers*

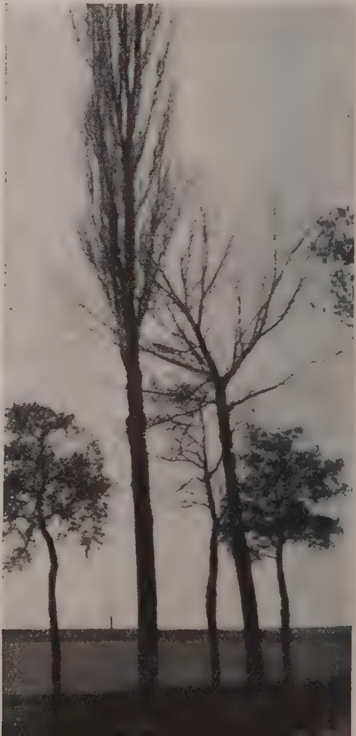
FIGURE 28 *b*). – *P.* 'serotina' and *P.* 'italica' at Echenon (Côte-d'Or, France); in the foreground, a 5-year-old *P.* 'robusta'.

Courtesy *J. Pourtet*

FIGURE 28 *c*). – *P.* 'serotina de Sélys' and *P.* 'serotina' at Waremme (Belgium). The habit of *P.* de Sélys is similar to that of *P.* 'italica', but it is late in leafing like *P.* 'serotina'.

Courtesy *R. G. Fontaine*





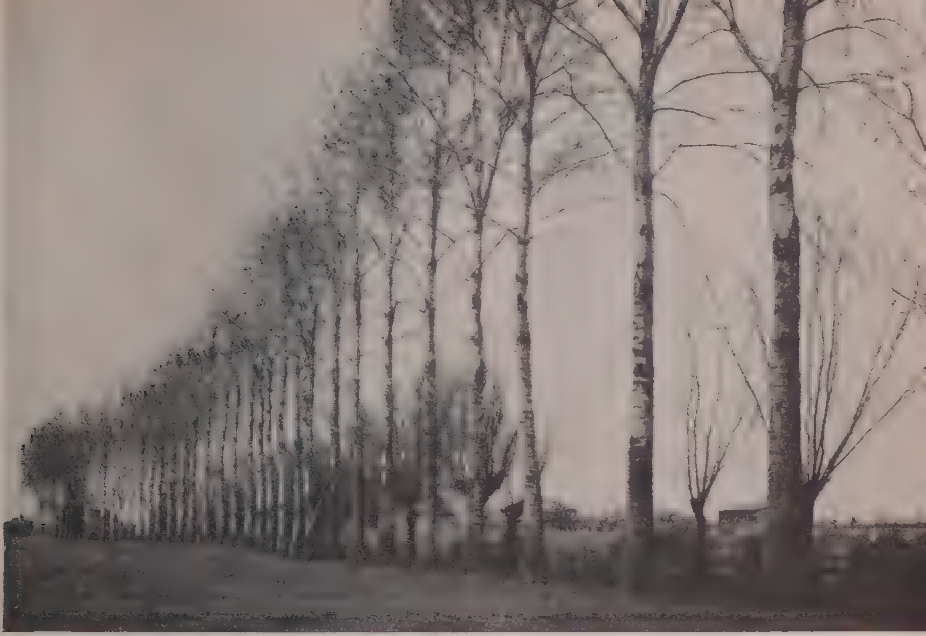
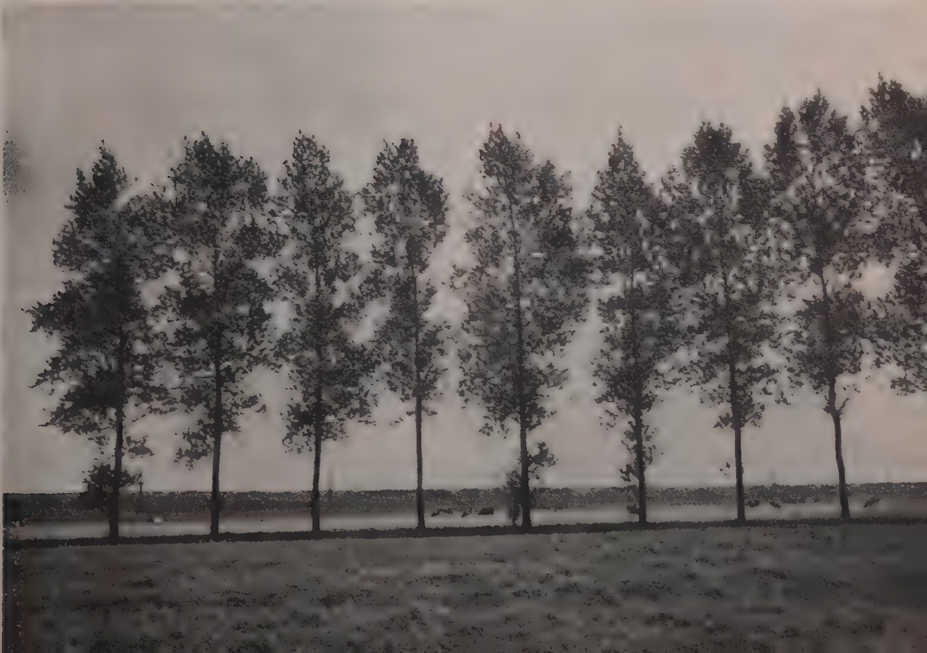


FIGURE 29. – *P.* ' gelrica ' with typical white bark.

Courtesy *Nederlandse Heidemaatschapp*

FIGURE 30. – *P.* ' serotina '. The crowns form a " sawtooth " line, whereas those of *P.* ' marilandica ' (*see* frontispiece) form a sinuous line.

Courtesy *Nederlandse Heidemaatschappij*



This strain is suited to sandy soils and to sites having a fairly high water table; it is unsuited to acid, marshy or peaty soils. It is resistant to sea winds, canker and *Dothichiza*.

POPULUS X EURAMERICANA (Dode) Guinier cv. ' gelrica '

This male hybrid is native to the Netherlands (Gueldre) where it is much cultivated; its leafing date is between that of *P.* ' marilandica ' and *P.* ' serotina erecta '; the leaves have a straight base and are a lighter green than those of *P.* ' serotina '. Nonwoody shoots are reddish in color, the petioles almost green. The bark is typically white. This is a very good hybrid and grows extremely rapidly. It is very adaptable and grows equally well in sandy and clay soils but is affected by acid or peaty soils. It is resistant to canker, *Dothichiza* and rust fungi.

POPULUS X EURAMERICANA (Dode) Guinier cv. ' regenerata '

In France, Belgium, the Netherlands, England and Germany, this is a collective name for several female clones, probably resulting from the cross *P. nigra* x *P.* ' serotina '. Selection of the best clones is now in progress, since there are many forms which are highly susceptible to weeping canker.

Leafing generally occurs at the same time as *P.* ' gelrica ' or several days later. Leaves have a straight base and are light green in color; petioles and nonwoody shoots are green. The catkins often fall before maturity, even before leafing. The tree has a very compact and vigorous root system and is therefore well suited to moist, marshy and peaty soils, as well as to acid soils with a relatively low pH. Its resistance to drought and sea winds appears to be inadequate.

POPULUS X EURAMERICANA (Dode) Guinier cv. ' eugenei '

This male hybrid is probably a cross of *P.* ' regenerata ' x *P. nigra* ' italica ' which originated in the Simon Louis nursery at Plantières-les-Metz, France.

Leafing occurs fairly early, at approximately the same time as *P.* ' marilandica '. The leaves are bright green and smaller than those of other Euramerican hybrids, often slightly wedge-shaped or straight at the base. Petioles and nonwoody shoots are green or very faintly reddish (round the buds). The tree has a fairly erect habit.

It seems to thrive on dryish soils but in fact is little known outside England, where it should be distinguished from another clone with the name of ' pseudo-eugenei ', which is highly susceptible to weeping canker.

POPULUS X EURAMERICANA (Dode) Guinier cv. ‘ robusta ’

This male hybrid also originated in the Simon Louis nursery at Plantières-les-Metz in 1895. It is considered to be a hybrid between *P. deltoides angulata* and *P. nigra plantierensis*, raised from a fairly extensive seeding; it is thus a mixture of clones, which is apparent, amongst other characters, in the varying degree of hairiness of the shoots and the different types of bark. Leafing occurs early, one or two days after *P. nigra italica* and *P. deltoides* ‘ missouriensis Dutch importation ’.

It closely resembles the latter but the nonwoody shoots are more reddish and the leaves a little shorter. The trunk is very straight, the crown erect and narrow.

P. ‘ robusta ’ grows in fairly light and dry soils (*Kippenaufforstungen* in Germany) as well as in acid soils. It is not at home on moist and badly drained sites where the water table is high. It is widely cultivated in France, Belgium, Germany and Great Britain, and is distributed throughout the world.

The following clones may also be mentioned: ‘ monilifera ’ (Italy); ‘ robusta Zeeland ’ (Netherlands) and ‘ vernirubens ’ (England, seedlings raised by Henry, 1914).

POPULUS X EURAMERICANA (Dode) Guinier cv. ‘ I-214 ’

This is a spontaneous female hybrid. Leafing occurs earlier than in Italian poplar and leaf fall is very late in the autumn.

Leaves: large and triangular with a short pointed apex and a straight or slightly rounded base; very young leaves reddish in color, adult leaves medium green.

Petiole: reddish, three quarters the length of the leaf blade.

Branching: rather dense; shoots are scattered, of medium thickness, round; young shoots red-brown; nonwoody shoots red, glabrous.

Flowers: green, compact, with 2 stigmas.

Fruit: tapering bivalve capsules, curving back slightly, pointed, producing a little cotton.

Habit: slender with semi-spreading crown.

It has a very rapid rate of growth and grows well even in unfavorable site conditions. It is resistant to the principal diseases (*Venturia populina* Vuill., *Phloeomyzus passerrinii* Sign., *Schizomycetae*, causing canker of the bark or bacterial infection, fungi causing root rot), and completely resistant to weeping canker.

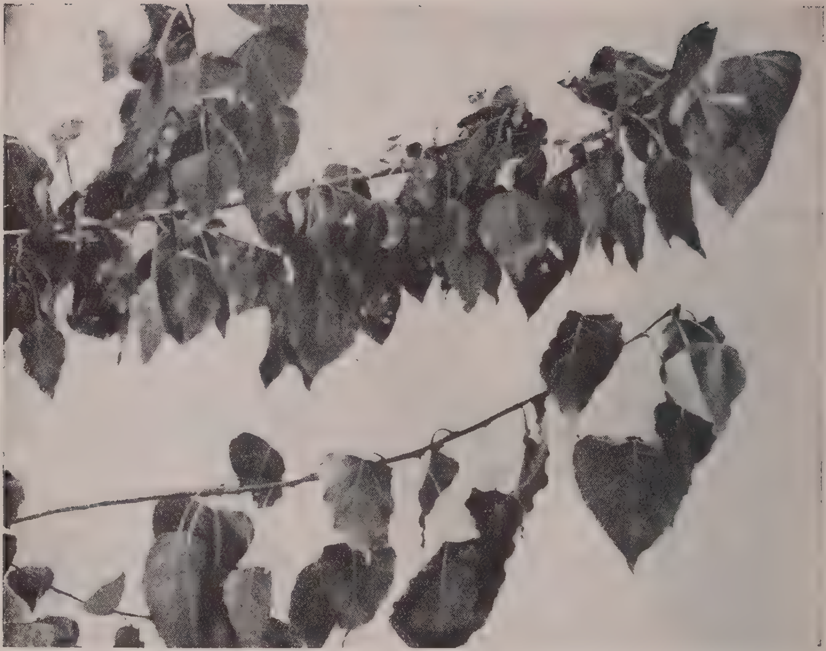


FIGURE 31. – Leafy shoots: *P.* x *euramericana* 'serotina' without short shoots (below) and *P.* 'robusta' with short shoots (above).

Courtesy *G. Houtzagers*

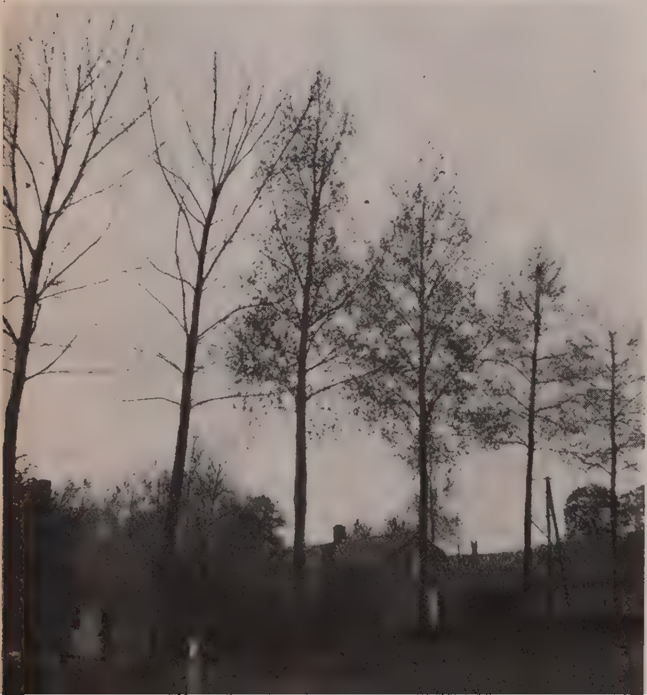


FIGURE 32. – Examples of different dates of flushing: left to right: two examples of *P.* 'serotina', two of *P. deltoides* 'missouriensis' Dutch importation and three of *P.* 'marilandica'.

Courtesy *Nederlandse Heidemaatschappij*

POPULUS X EURAMERICANA (Dode) Guinier cv. ' I-154 '

This was the first hybrid to be raised by the *Istituto di Sperimentazione per la Pioppicultura,* Casale Monferrato. It is male.

Leaves: yellowish when they unfold, which is later than for ' I-214 '.
Habit: not very slender, with sinuous trunk and spreading crown.

Well suited to hot, dry climates, it is susceptible to weeping canker and should not be grown in northern regions. It is of great economic importance in Italy as well as in South America, particularly Argentina and Chile, where it is known by the initials ' A.M. '

POPULUS X EURAMERICANA (Dode) Guinier cv. ' I-455 '

This is a spontaneous female hybrid.

Leaves: medium-sized, triangular-pointed, with a straight leaf base, light green in color when unfolding, dark green later.

Shoots: scattered, fairly thin; nonwoody shoots green or reddish.

Habit: erect, bole straight.

The rate of growth is slower than that of ' I-214 '. As the crown is only slightly spreading it can be recommended for roadside and hedgerow planting. It is highly resistant to the principal diseases which attack poplars in Italy and is not very demanding as to soil conditions.

These last three clones root exceptionally well from cuttings even in poor conditions.

Other hybrids are at present under test in Italy (I-262, I-72/51, I-45/51, I-37 AD, etc.) and in other countries, but as yet not enough is known about them to recommend their cultivation on a wide scale. However, in Spain certain Euramerican hybrids are widely cultivated: their origin is obscure and at the present stage of international research it does not seem possible to relate them to any one of the types described above. Their botanical description is still incomplete, so mention will only be made here of two of them, pending the results of the comparative studies now in progress.

POPULUS X EURAMERICANA cv. ' Canada blanc '

A very fine tree, flushing relatively early, with a smooth, white, velvety bark and fairly spreading crown. It is a male clone with a rapid growth rate, and is of importance in Catalonia.

POPULUS X *EURAMERICANA* cv. ' Negrito de Granada '

This probably male clone has a distinctly earlier date of flushing than the previous clone. It has an erect habit and grows very tall. It grows chiefly in Andalusia.

D. SECTION *TACAMAHA* - Balsam poplars

The description of this section requires far less elaboration than the preceding sections since, even though certain species may constitute natural stands of economic importance, their cultivation will never attain an importance comparable with that of *Leuce* and particularly *Aigeiros* poplars.

Although for the most part of northern origin, the majority of the species belonging to this section cannot be grown over a large part of the cold temperate zone of Europe on account of their extreme susceptibility to weeping canker. Moreover, they do not benefit from a long growing season and are very vulnerable to attack by many insect or plant parasites.

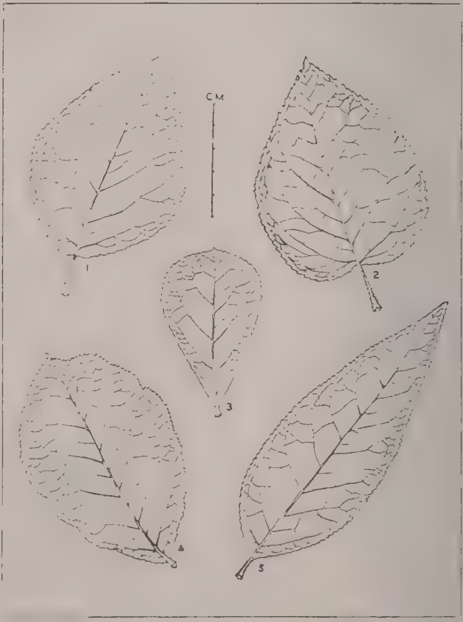


FIGURE 33. – Types of balsam poplar leaves.

1. *Populus tacamahaca*
2. *Populus candicans*
3. *Populus simonii fastigiata*
4. *Populus maximowiczii*
5. *Populus trichocarpa*

Their requirements as to light, water and soil quality are approximately the same as those of black poplars.

Balsam poplars can be rooted very easily from cuttings.

They are native to east Asia and North America only, and no indigenous species are represented in Europe.

ASIA

The species indigenous to this continent are very numerous, but little is known about them and it is difficult to estimate their exact importance, which must, however, be closely connected with the local economy of sparsely wooded regions.

POPULUS LAURIFOLIA Ledeb.

This is a small tree with relatively narrow leaves, originating in southern Siberia, rarely cultivated in Europe, but with a certain interest for cold or "continental type" countries. It is known chiefly by its hybrids with *P. nigra* (*see below*).

POPULUS SUAVEOLENS Fisch.

Very widely distributed from Turkestan to Kamtchatka. In central Asia it is frequently one of the only woody species to attain tree dimension and is known by the name of "Toghrak." Its leaves are of medium size, ovate-rhombic or more or less round at the base, pointed at the apex.

Populus maximowiczii Henry, of Japan, where it is sometimes planted, and *P. koreana* Rehd. of Korea and Japan, which comes into leaf earlier than any other poplars.

POPULUS SIMONII Carr.

Distribution extends from western China to Korea. Although very variable, this species is always characterized by slender flexible shoots strongly angled when vigorous, and leaves which are small, elliptic, rhombic, and often obovate on long shoots. Adult trees, which never attain large dimensions, have a smooth bark and a drooping habit. Frequently planted in the mountainous regions of France at the end of the last century, it has not yielded encouraging results. It is planted in France in parks and along streets. A fastigiate form exists (*P. simonii fastigiata* C.S.) which is suitable for windbreaks around orchards.

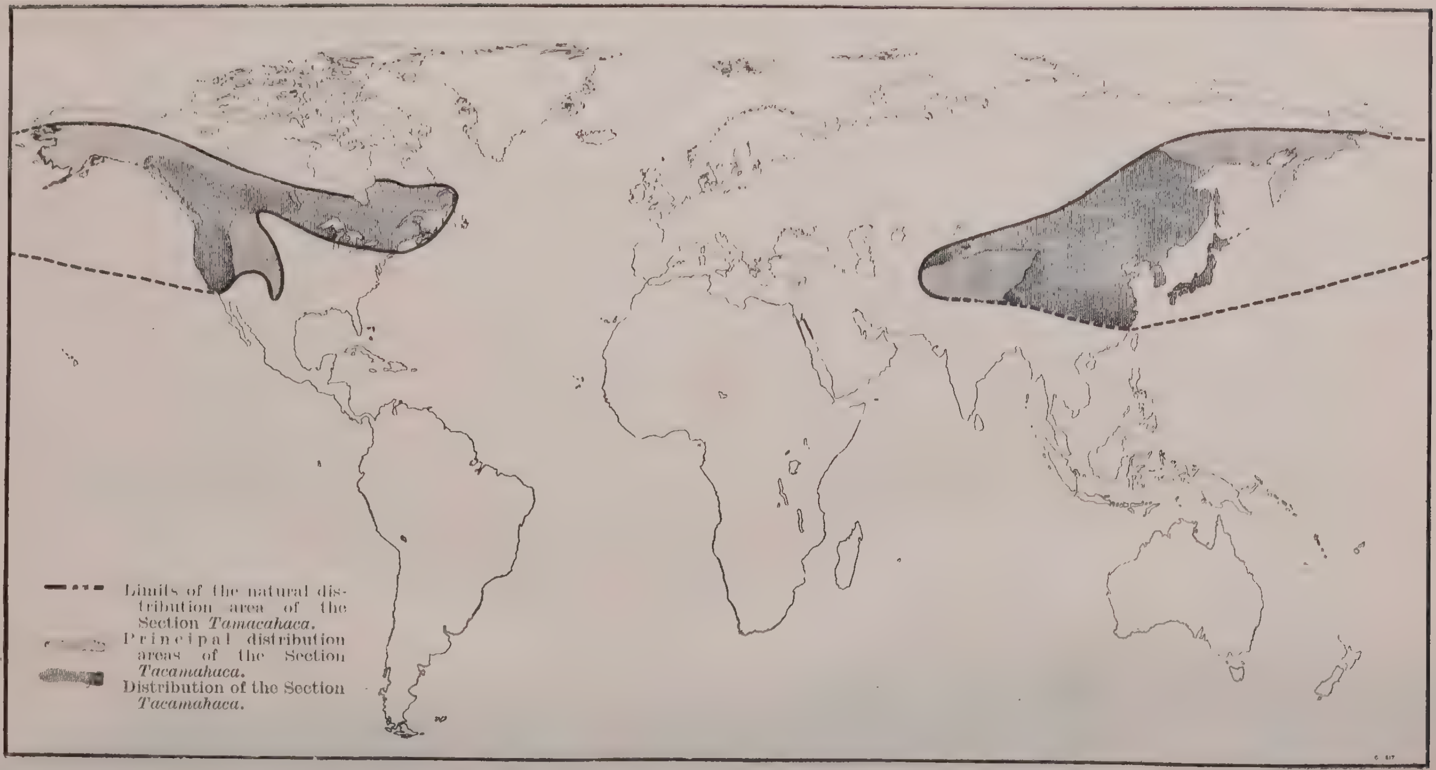

Limits of the natural distribution area of the Section *Tamacahaca*.
Principal distribution areas of the Section *Tacamahaca*.
Distribution of the Section *Tacamahaca*.

FIGURE 34. – World distribution of balsam poplars (Section *Tacamahaca*).

POPULUS YUNNANENSIS Dode

A tall tree with a fine habit from southern China. It grows rapidly but requires a hot climate and a long growing season; on the other hand, it is very adaptable to soil conditions.

Its reddish shoots are strongly angled, its leaves large and dark green in color, similar in shape to those of *P. deltoides*.

It appears to be giving good results in the south of France, where it is being tried out in forest plantations.

NORTH AMERICA

Two species of balsams are of considerable economic importance in the U.S.A. and Canada but it is difficult to estimate this importance precisely, since their timber is often used indiscriminately with that of aspens and other broadleaved species. It is sometimes difficult to differentiate between these two species in the west, where their areas of distribution partially overlap.

POPULUS TRICHOCARPA Torr. and Gray (including var. *hastata* Henry) - Black cottonwood

This species has a vast distribution in the west of North America, stretching from southern Alaska to south California and from the Pacific coast to the Rocky Mountains (British Columbia, Washington, Oregon, Montana, Idaho). Here it attains considerable dimensions and can form dense forests along rivers, although it is more often found in mixed stands – in the north with Douglas fir, Sitka spruce, giant Thuja, *Abies grandis* and willow, and in the south in the mountains with *Libocedrus decurrens*.

It prefers a moist climate; away from the oceanic influence and a very humid atmosphere its dimensions are appreciably smaller (the Montana strains, for example).

Its leaves are ovate, tapering or lanceolate, wedge-shaped at the base, long-pointed at the apex; 12 to 14 centimeters in length and 5 to 8 centimeters wide. The upper surface is dark green in color, the lower surface whitish with a metallic luster. The petiole is long — 2 to 3 centimeters — and reddish in color. Vigorous one-year-old shoots are angled and slightly downy at first like the petioles. The buds are sharp-pointed, adpressed and tapered. Growth is rapid and the bole generally of good shape.

Rarely planted in Europe outside arboreta, it is now beginning to be studied for the selection of clones suitable for certain humid mountain regions and, if proved resistant to canker, also for very wet oceanic regions (Great Britain).

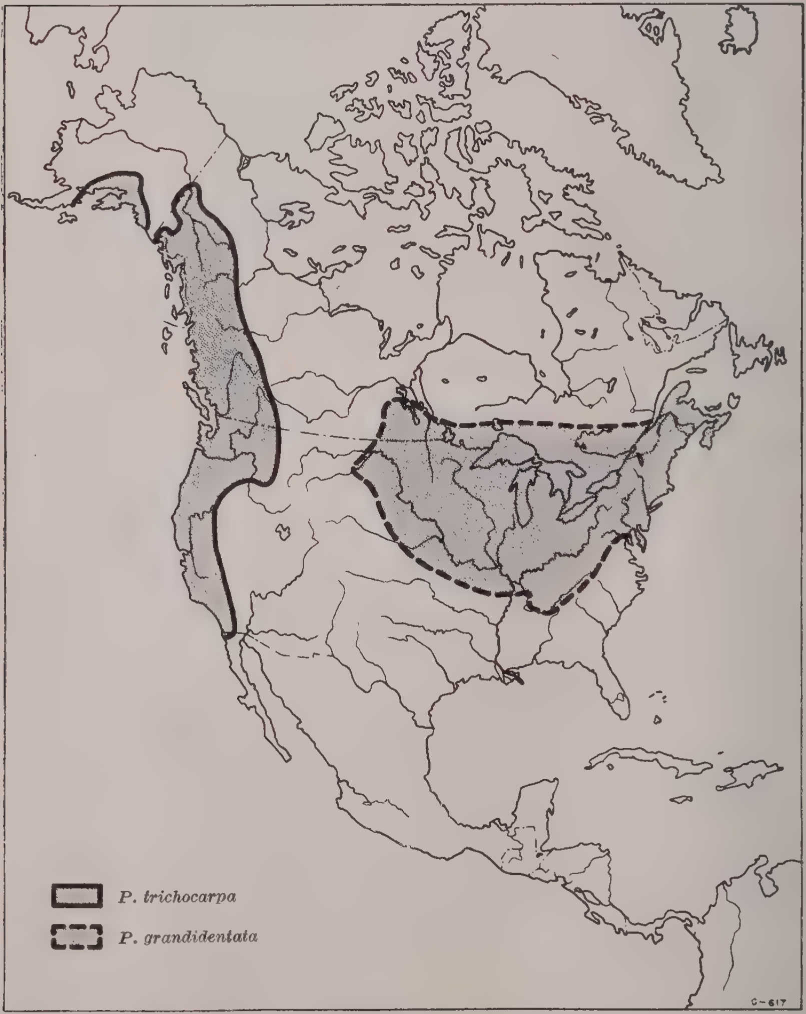


FIGURE 35. – Distribution of *Populus trichocarpa* Torr. and Gray and *Populus grandidentata* Michx.

POPULUS TACAHAMACA Mill. - *P. balsamifera* Duroi non L.

The distribution of this is even greater than that of the preceding species; it overlaps with it in Alaska and the Rocky Mountains and extends to the east over the whole of Canada from the northern tree line to latitude 45° N. in the U.S.A. It is found even further south in certain mountain ranges.

It is a much smaller tree than *P. trichocarpa*. Resistant to cold and to extreme conditions of wind and drought (it is planted in shelterbelts on the "Great Plains," for example), it is also found in natural stands in the "bottomlands" along rivers, lakes and marshes, sometimes in pure stands but more often mixed with willows, alder, birch and spruce (*Picea glauca* and *mariana*).

In the southern part of its distribution (in the vicinity of the Great Lakes) it usually grows in compact groups of small trees.[5]

The leaves are thick, leathery and ovate, round or shallowly heart-shaped at the base, flat-pointed at the apex, the upper surface dark green, the undersurface having a metallic luster. One-year-old shoots are almost round and like the petioles glabrous.

The cultivation of this tree outside its natural distribution does not seem promising.

POPULUS CANDICANS Ait. - *P. gileadensis* Rouleau

Balm of Gilead. A species or form very closely related to that preceding; its distribution is, however, slightly less extensive and is probably artificial. *P. candicans* is only known as a female tree. Its leaves are larger and more heart-shaped, with pubescent young growth and petioles. This poplar suckers, as does the foregoing species. It is planted extensively in Canada in row plantations — in towns and as windbreaks — and is very often grown as an ornamental tree in western and particularly northern Europe (often with *P. tacamahaca*). It gives good results in the slightly peaty soils of the mountains of eastern France (the Jura), where its growth rate is very rapid, at least when young.[6]

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[5] It hybridizes spontaneously with *P. deltoides* Marsh., for example *P. x jackii* Sarg., "Northwest poplar," etc.

[6] Two small trees growing in the Rocky Mountains may also be mentioned: *P. angustifolia* James, the leaves of which resemble those of a *Salix* or peach tree, and *P. acuminata* Rydb., which is sometimes considered to be a hybrid of the former with *P. sargentii*.

BLACK X BALSAM HYBRIDS - *Tacamahaca* x *Aigeiros*

These hybrids, which are produced naturally in America, have been cultivated in several countries; although interesting from the experimental point of view and for the great ability with which they can be rooted from cuttings, they have on the whole proved disappointing in practice, chiefly on account of their high susceptibility to parasites and particularly to weeping canker.

The following hybrids deserve mention:

Populus x *generosa* = *P. deltoides angulata* x *P. trichocarpa*

An artificial hybrid raised by Henry at Kew (1914).

A large number of strains, both male and female, have resulted from this hybridization, and all have been commercialized under the name of *P. generosa.* As a group they have the following characters: an extremely rapid rate of growth when young, very broad shiny green leaves with red veins on the upper surface and pale green or grayish veins on the undersurface, rather round at the base, the apex long-pointed. The petiole is round at the base and compressed toward the blade; it is reddish in color. One-year-old shoots are angled and glabrous. Leafing occurs early, approximately at the same time as *P. deltoides angulata.* All these strains are highly susceptible to rust and to canker. In fact, not too much faith should be placed in this hybrid, particularly since it is subject to windblow because of its very fragile wood, and its initial rapid rate of growth soon falls off.

The poplar propagated under the name of "McKee poplar" is a female hybrid raised in the United States, and has the same parents as *P. generosa*: it has been planted widely in Belgium and France since the second world war. It is very susceptible to weeping canker and its cultivation is definitely in decline.

Populus x *berolinensis* Dippel

Originated in the botanical gardens of Berlin. It is a seeding from *P. laurifolia*, pollinated probably by *P. nigra* 'italica'. Both male and female trees exist. It is characterized by its narrow crown, fastigiate branching and long ovate leaves (7 to 12 centimeters long, 4 to 7 centimeters wide) bright green on the upper surface, grayish-green beneath. As a wood producer *P. berolinensis* has no great value because of its feeble growth rate, but it can be used for roadside planting and as windbreaks, as well as on fairly dry sites. It is not completely canker-resistant and is sometimes attacked when young by *Dothichiza*. Leafing occurs early, approximately at the same time as *P. candicans*.

Several other very similar hybrids from *P. laurifolia* may be associated with *P.* x *berolinensis*: *P. rasumowskyana* Schr. and *P. petrowskyana* Schr.

P. berolinensis, a male clone, has been used by Stout and Schreiner in various hybridizations with *P. maximowiczii* Henry, of which two — "Geneva poplar" and "Oxford poplar" — may be singled out from the ten selected at Frye (Maine, U.S.A.) in 1934 as having very good growth. Unfortunately, artificial inoculation has proved that these two forms are not sufficiently resistant to weeping canker, and it remains to be seen whether this susceptibility is borne out in nature.

E. SECTION *LEUCOIDES*

This section, which is fairly extensively represented in the Far East, also includes one species which is found in the east of North America. However, no tree from this section is of any appreciable economic importance.

The leaves, which vary little in shape, are very large, heart-shaped, and downy at first underneath. They are difficult to root from cuttings.

ASIA

POPULUS LASIOCARPA Oliv. - *P. fargensii* Franch.

Distribution: little known in central and western China.

Distinctive characters

Particularly characteristic of the tree are its very large heart-shaped leaves, slightly leathery on the upper surface and paler in color underneath. The shoots are very large. Leafing occurs very late. The catkins which enclose both male and female flowers are self-fertilizing. The rhytidom develops early and is fissured into long plates. This is a tree of secondary dimensions but with a rapid growth rate: it does not appear to be of interest other than for ornamental purposes.

Growth characteristics

Rooting from cuttings is rather difficult but grafting onto poplars of the *Aigeiros* section is possible; seeding can also be practiced successfully, due chiefly to the hermaphroditism of the catkins.

Stool shoots are extremely strong and vigorous.

POPULUS WILSONII Schneid. and *violascens* Dode

Also native to China, they are even less known than the preceding species.

POPULUS CILIATA Wall.

A very large tree, having a considerable distribution in the Himalayas. Little is known about it and it is perhaps related to the balsam group. Dode has given a separate description for *P. jacquemontiana* which is probably only a form of *P. ciliata* (Kashmir).

NORTH AMERICA

POPULUS HETEROPHYLLA L. - Swamp cottonwood

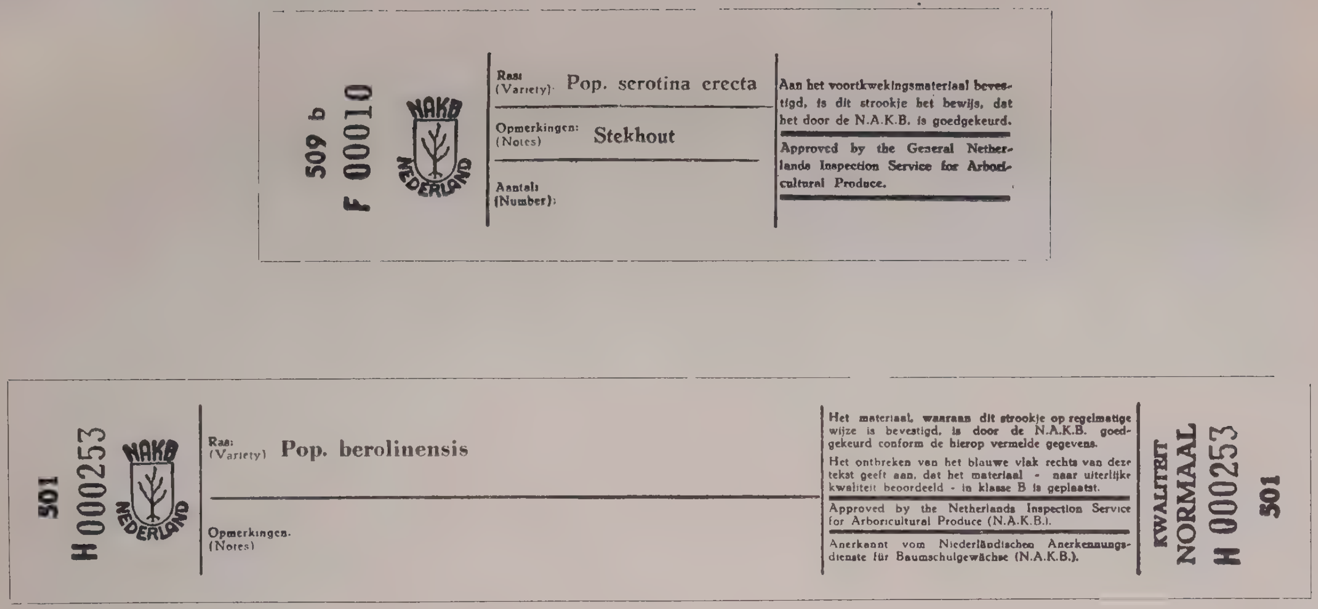
This tree has an extensive but scattered distribution, comparable with that of *P. deltoides*, although it is a more southerly species. In spite of its size this tree has no commercial importance and is grown solely, and then only rarely, in dendrological arboreta.

Contrary to its name, its leaves are particularly uniform in shape. Propagation from cuttings is very difficult.

III. VARIETAL CONTROL

The need for varietal control, because of the rapid increase in artificial hybrids in various countries, and the extended practice of exchanging cuttings and plants between countries, has already been discussed. The use of plants and cuttings of certified origin and identity, resistant to disease and belonging to types capable of producing marketable assortments of timber, is essential to good national and international poplar cultivation. Some countries have already solved this problem in various ways, either summarily on a voluntary participation basis, or more comprehensively with the introduction of strict regulations. It is interesting to note the principles adopted in various countries along very different lines, and a few examples are quoted here.

In the *Netherlands* a strict and complete varietal control has been in force since 1943; it is carried out by an official control body known as the N.A.K.B. (*Nederlandse Algemene Keuringsdienst voor Boomkwerkerijgewassen*, or General Netherlands Service for the Inspection of Trees.) The control exercised by this body is concerned particularly with species, hybrids and varieties of major importance to horticulture and sylviculture.



509 b
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NAKB NEDERLAND

Ras: (Variety): Pop. serotina erecta

Opmerkingen: (Notes) Stekhout

Aantal: (Number):

Aan het voortkwekingsmateriaal bevestigd, is dit strookje het bewijs, dat het door de N.A.K.B. is goedgekeurd.

Approved by the General Netherlands Inspection Service for Arboricultural Produce.

501
H 000253

NAKB NEDERLAND

Ras: (Variety) Pop. berolinensis

Opmerkingen. (Notes)

Het materiaal, waaraan dit strookje op regelmatige wijze is bevestigd, is door de N.A.K.B. goedgekeurd conform de hierop vermelde gegevens.

Het ontbreken van het blauwe vlak rechts van deze tekst geeft aan, dat het materiaal - naar uiterlijke kwaliteit beoordeeld - in klasse B is geplaatst.

Approved by the Netherlands Inspection Service for Arboricultural Produce (N.A.K.B.).

Anerkannt vom Niederländischen Anerkennungsdienste für Baumschulgewächse (N.A.K.B.).

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FIGURE 36. – Poplar labels used by the N.A.K.B. in the Netherlands.
(3/4 actual size)

For poplars, a *list of strains* of importance in poplar cultivation has been drawn up and nurserymen who are members of the inspection service — all of any importance — are not permitted to grow or sell types other than those officially listed. In addition, they are obliged to buy their growing stock from the central nursery of the *Nederlandsche Heidemaatschappij*, which is responsible for the selection of poplars and, in conjunction with various official bodies, distributes under the seal of the N.A.K.B. cuttings of strains selected and tested for their resistance to disease. Young plants raised from these cuttings must then be sold with the seal of the N.A.K.B., which exercises permanent control over its member nurseries. Further, these cuttings may be used as stools from which the nurseryman is allowed to take his own cuttings each year, again under the supervision of the N.A.K.B. Young trees raised from the latter can also be sold with the official seal but only as "secondary stock."

When a nurseryman or selector has chosen a new form of poplar, it cannot be commercialized with the N.A.K.B. guarantee until it has undergone tests for at least three years in the central nursery of the *Nederlandsche Heidemaatschappij*; these tests include, amongst others, artificial inoculation with bacterial exudation of weeping canker for three successive years. Only completely resistant strains of good habit and growth are authorized for sale and can then be distributed under the control regulations and seal described above.

Clearly, these regulations, which perhaps at first sight appear rather severe, give a very adequate guarantee not only of identity and origin but also of health. In the Netherlands, nurserymen have come to realize that the control is not onerous and that its good results have brought about a considerable expansion of cultivation generally.

In *Belgium* a more or less similar control has been carried out since 1949 by the O.N.D.A.H. (*Office national des débouchés agricoles et horticoles* [Office for the Marketing of Agricultural and Horticultural Produce]) over member nurseries (membership is optional), and only for the types of poplar included in the official list published annually by the Ministry of Agriculture.

Cuttings are not supplied by a central nursery but supervision is exercised by the O.N.DA.H. on the ground and at the time of selling, to ensure that the produce of member firms reaches the required standards of identity, quality and health.

Plants which are up to standard can be sold with the O.N.D.A.H. seal which is attached individually to each plant of 2 years of age and over, and to each bundle of 25 one-year-old plants.

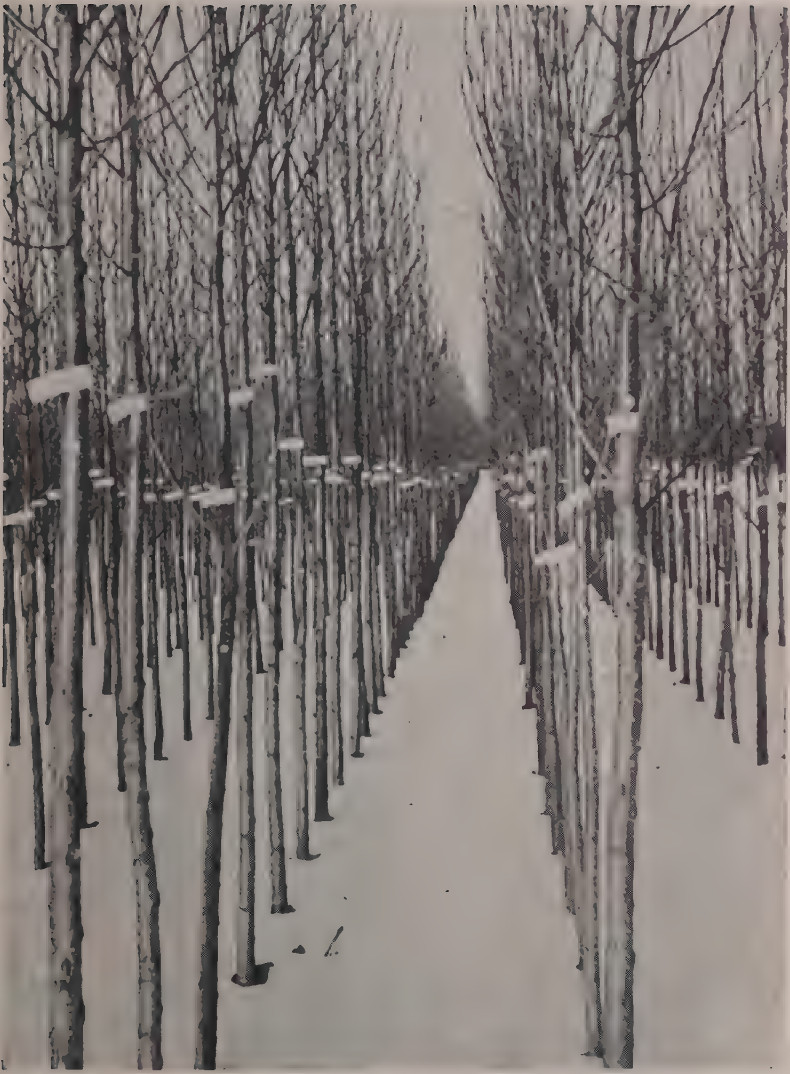


FIGURE 37. The central nursery of the *Nederlandsche Heidemaatschappij* at Keppel, Netherlands (each plant bearing a label).

Planters soon realize that results justify the higher price paid for stock certified in this way.

In *France* a ministerial decree of 31 October 1950 approved a list of poplar species or types which alone could be sold as "species for forest and line plantings." For the cultivation of these a grant is paid by the state. (The sale of other poplars is free of control but only as "ornamental trees.") This list may be subject to revision and addition if tests prove the economic value of other types.

Catalogues, labels and other trade documents must all conform to the nomenclature approved by the decree, which has also set standards as to age, dimensions and health.

No control is carried out in the nurseries themselves but the *Service de la répression des fraudes* (service to prevent misrepresentation) can visit them, take samples and, if necessary, take legal action if an infringement of the law is proved.

In addition, a central nursery of stool beds, directed by the *Station de recherches et expériences forestières* (Forest Research Station) distributes to individuals or bodies, on request, certified cuttings for propagation purposes. This service is rendered under the auspices of the National Poplar Commission.

In *Italy* an even more liberal system has been in force since 1952; control is completely optional, and nurserymen are free to request it if they wish to obtain recognition and guarantee of the clones they have raised. Individuals are likewise at liberty to plant stock carrying no guarantee.

The National Poplar Commission has therefore merely established "the conditions which will ensure the quality and improvement of material for propagation," and with the aid of the *Direzione Generale dell'Economia Montana e delle Foreste* and the *Ente Nazionale per la Cellulosa e per la Carta*, it anticipates the certification and registration of clones.

IV. INTERNATIONAL REGISTRATION OF POPLAR NAMES

The increase in selections and hybrids of poplar in different countries makes a comprehensive international register of their names more and more imperative. The aim of registration is self-evident — to avoid using the same name for different plants and, conversely, the unnecessary creation of new names.

Therefore, at its eighth session in 1955, the International Poplar Commission agreed to become the international authority responsible for registration. It invited its member countries to submit to the secretariat at Rome a list of their cultivated poplars and new selections of sufficient economic importance to warrant registration. The names proposed will be examined by a subcommittee set up for this purpose, before being put before the Commission itself for decision.

To obtain uniformity, member countries are advised to use the simplified identification form (*see* Appendix 5) for describing poplars submitted for registration.

Appendix 1

Key to the identification of poplars in the following sections: *Turanga, Leuce, Aigeiros, Tacamahaca* and *Leucoides*

1.	Leaves suborbicular or lobed (trilobed or palmately lobed), varying widely on short shoots and long shoots. Bracts jagged and ciliate (catkins hairy) Bark smooth, light colored, fairly persistent	Section *Leuce* 2
	Leaves triangular, rhombic, elliptic or ovate. Bracts nonciliate. Rhytidom on the whole develops early	3
2.	Young shoots and buds downy, likewise the undersurface of leaves. Petioles almost cylindrical, at least for long-shoot leaves	Subsection *Albidae* White Poplars, 6
	Young shoots and buds glabrous, or only slightly pubescent. Short-shoot leaves suborbicular, always glabrous; long-shoot leaves ovate, glabrous or temporarily downy. Petioles compressed	Subsection *Trepidae* Aspens
3.	Leaf margins translucent	4
	Leaf margins not translucent. Petioles round, not compressed.	5
4.	Leaves triangular or rhombic, green on both surfaces. Petioles compressed Buds viscid but not very odorous	Section *Aigeiros* Black Poplars, 8
	Leaves grayish, leathery, very polymorphic. Petioles slightly compressed Buds dry	Section *Turanga* *P. euphratica*
5.	Buds very viscid with a persistent balsamic odor. Leaves ovate, more or less tapered, heart-shaped or wedge-shaped at the base, undersurface white with a metallic appearance	Section *Tacamahaca* Balsams
	Buds less viscid and very big; very large heart-shaped leaves, undersurface not white but more or less pubescent	Section *Leucoides*
6.	Undersurface of leaves clothed with a persistent white down. Long-shoot leaves lobed	7
	Undersurface of leaves clothed with a grayish more or less persistent down. Long-shoot leaves with sinuous toothing	*Populus* x *canescens*

7.	Long-shoot leaves palmately lobed, clothed with a very thick, pure white down	*Populus alba* var. *nivea*
	Long-shoot leaves palmately lobed, covered with a grayish-white down; fastigiate habit	*Populus* 'bolleana' *Populus alba* 'Roumi'
	Long-shoot leaves toothed or with 2 lateral lobes. Very white undersurface	*Populus alba* var. *hickeliana* and *subintegerrima*
8.	Section *Aigeiros* - Black poplars Vigorous shoots cylindrical, leaves rhombic to ovate, base often wedge-shaped. Leaf margin never ciliate. Female trees have globular capsules opening into 2 valves	*Populus nigra* L.
	Vigorous shoots more or less angled, ribbed longitudinally. Leaves triangular truncate or heart-shaped, rarely wedge-shaped at the base. Leaf margin ciliate, at least at time of opening	9
9.	Two glands at leaf base, which is truncate or heart-shaped. Capsules open into 3 to 4 valves	*P. deltoides*
	Glands sometimes present (0,1 or 2). Leaf base truncate or slightly wedge-shaped. Female trees have capsules opening into 2 or 3 valves	*P.* x *euramericana*

APPENDIX 2

ECOLOGICAL AND ECONOMIC CHARACTERISTICS OF THE FIVE SECTIONS OF THE GENUS *Populus* (*see* text for the Section *Leucoides*, which is of minor importance)

Sections		*Turanga*	*Leuce*		*Aigeiros* Black poplars	*Tacamahaca* Balsam poplars
			Albidae White poplars	*Trepidae* Aspens		
Climate		arid; subtropical, even continental	temperate or hot temperate to subtropical, even arid	temperate or cold temperate to subboreal	temperate or hot temperate	temperate or cold temperate
Soil		well watered, even with salt water	indifferent, even to salt	indifferent; prefers clay soil, even if very moist	requires rich, moist, well-aerated soil; dislikes stagnant water	requires rich, moist soil
Sociability		social	very social	very social	fairly social (dislikes high density and competition)	fairly social
Method of propagation	natural	seed root suckers	seed root suckers	seed root suckers	seed	seed (sometimes root suckers)
	artificial	coppice shoots (cuttings)	coppice shoots cuttings	coppice shoots (seed)	(coppice shoots) cuttings	coppice shoots cuttings
Economic importance	natural stands	in Near East for rural economy	great importance to rural economy in circum-Mediterranean region	very great in northern region	fairly great in east of North America, relatively low elsewhere	great in North America; fairly great in North-east Asia
	plantations	none	fairly great in Near East	low but increasing	very great in west and central Europe and in Near East	none

APPENDIX 3

GEOGRAPHICAL CLASSIFICATION OF THE GENUS *Populus* L.

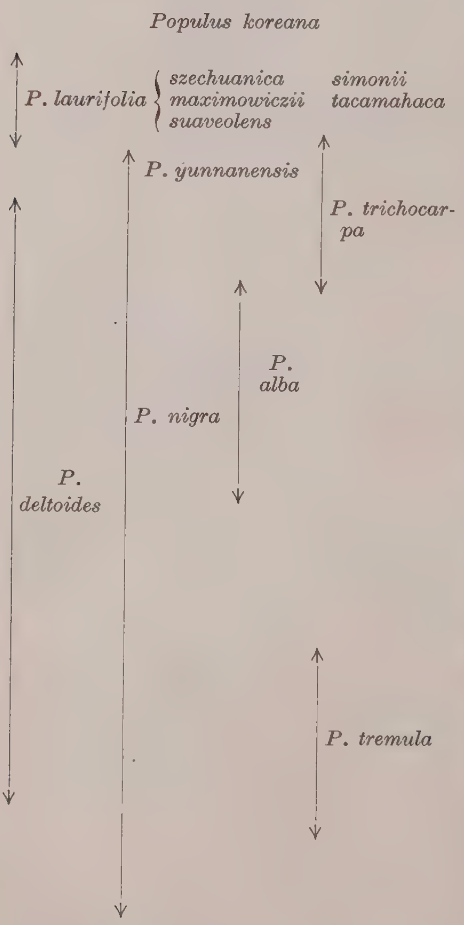
Sections	Europe West Asia North Africa	East Asia China, Japan	North America (East)	North America (West)
Turanga	*euphratica*			
Leuce: White poplar group	*alba* and varieties	*alba tomentosa*		
Aspen group	*tremula*	*tremula, sieboldii, davidiana*	*grandidentata, tremuloides*	*tremuloides*
Aigeiros	*nigra* and varieties		*deltoides* and subspecies	*sargentii* *fremontii* *wislizenii*
Tacamahaca		*koreana* *maximowiczii* *suaveolens* *laurifolia* *simonii* *yunnanensis*	*tacamahaca*	*trichocarpa* *tacamahaca* *angustifolia*
Leucoides		*lasiocarpa* *violascens* *wilsonii*	*heterophylla*	

APPENDIX 4

LEAFING OF POPLARS

(ranging from very early to very late)

Species, subspecies and varieties



Clones and cultivars

P. simonii ' fastigiata '
P. candicans
P. x *berolinensis*

P. x *euramericana* ' I-214 '
P. deltoides ' carolinensis '
P. ' bolleana '
P. deltoides ' missouriensis Dutch importation '
P. x *generosa*

P. nigra ' italica '

P. x *euramericana* ' robusta '
P. deltoides ' angulata de Chautagne '
P. x *euramericana* ' I-154 '

P. x *euramericana* 'marilandica'
P. x *euramericana* ' eugenei '
P. deltoides ' monilifera '
P. deltoides ' virginiana '

P. x *euramericana* ' gelrica '

P. x *euramericana* ' regenerata '
P. x *euramericana* ' serotina de Champagne ' and ' erecta '

P. x *euramericana* ' serotina du Poitou'
P. x *euramericana* ' serotina de Sélys '

P. x *euramericana* ' serotina '
P. nigra ' Hamoui '

NOTE: When comparing the relative dates given in these two columns it should be borne in mind that in the first column are listed populations consisting of individual trees or groups of trees whose leafing period varies. The date is therefore only intended to give an indication (*P. nigra* ' *italica* ' is used as reference species).

Appendix 5

Description card of spontaneous or cultivated poplars

I. General information

Section:
Common name:

Latin name of species (to which it is related):

Name it is proposed to homologate:

Trees considered: cultivated or spontaneous [1]

Site description of type under consideration:

a) Geographic location
  - region:
  - locality:
  - altitude:

(Location of site or sites where analogous types are observed and, if possible, an indication of their extent:

b) Soil:

c) Climate: [2]

II. Botanical information

Sex:

Date of foliation:

Date of defoliation: early - late - intermediate [1]

Long-shoot leaves (healthy non-branching shoots of the year)
  - Shape (sketch)
  - Petiole
    - average length
    - cross section (circular or flattened)[1]
  - Color on foliation
  - Possible presence of " downiness " on adult leaves
    - upper side
    - lower side

---

[1] Delete what does not apply.

[2] Climate should be defined either by relating it to a well known classification or by giving as much information as possible on temperature, precipitation, etc.

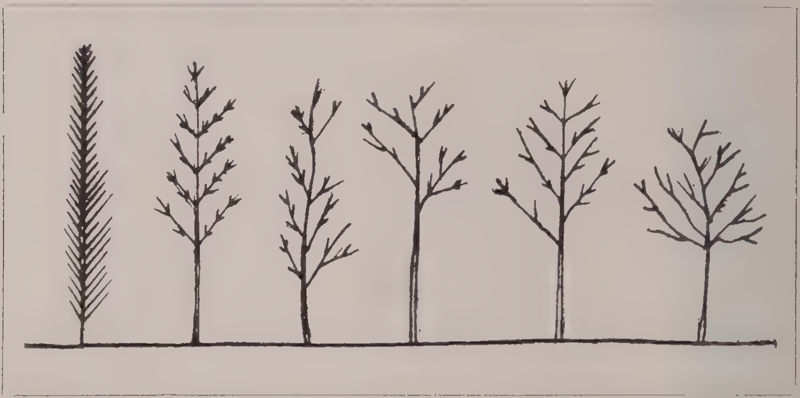
Short-shoot leaves
- Shape (sketch)
- Petiole
  - average length
  - cross section (circular or flattened)[1]
- Color on foliation
- Possible presence of "downiness" on adult leaves
  - upper side
  - lower side

Male flowers:[2] date of flowering - appearance

Female flowers:[2] date of flowering - appearance

Fruit: length and appearance of clusters
shape and number of capsule valves

Habit (at from 5 to 20 years of age, and not deformed by pruning)
(check corresponding silhouette and if possible attach a photo of the tree)



Habit of poplars (from 5 to 20 years, not distorted by pruning)

Trunk: very straight - fairly straight - forked or branching near ground[1]

Appearance, color and thickness of bark
- young trees:
- adult trees (over 20 years):

Branches
- shape, dimension and disposition of branches:
- color of woody branches:

III. INFORMATION ON PESTS AND DISEASES

Leaf parasites:
Branch parasites:
Trunk parasites:

Note: For each parasite indicate incidence and damage observed.

---

[1] Delete what does not apply.

[2] For cultivated types, delete what does not apply.

IV. INFORMATION ON USE OF POPLAR UNDER CONSIDERATION

Cultural (or silvicultural) methods:

Methods of propagation: by growing cuttings in nursery
by planting cuttings direct
use of root suckers
others

V. INFORMATION ON USE OF WOOD

Size and age of tree at felling:

Logging methods (felling, transport and bucking):

Uses: *a*) according to conversion method: sawing, slicing, peeling, pulping
b) according to products: packaging, plywood, matches, carpentry, fuelwood and paper pulp

Wood properties:

POPLAR CULTIVATION

Poplar cultivation, as has been emphasized in the introduction, may be considered from two different aspects: intensive, or cultivation outside the forest, and extensive, or cultivation in the forest. In both cases the aim is to obtain stands with a high or improved rate of productivity. The differences between these two types of cultivation are due mainly to the site conditions on which they are practiced and to the techniques employed.

In the first case, one or more [1] poplar types carefully selected on the basis of site conditions and the products to be obtained, are established in the best natural conditions, improving them if necessary by the usual agricultural techniques: preparation of the ground, application of manures, irrigation or drainage, etc., and by giving the trees constant attention so as to obtain the best quality timber. Hence, in this type of cultivation, the poplar is frequently combined with farm or forage crops, and is either planted among them or else the young stands are interplanted with crops. Intensive cultivation, which very often benefits from agricultural methods and manpower, depends fundamentally on the choice of clone and on efficient cultivation.

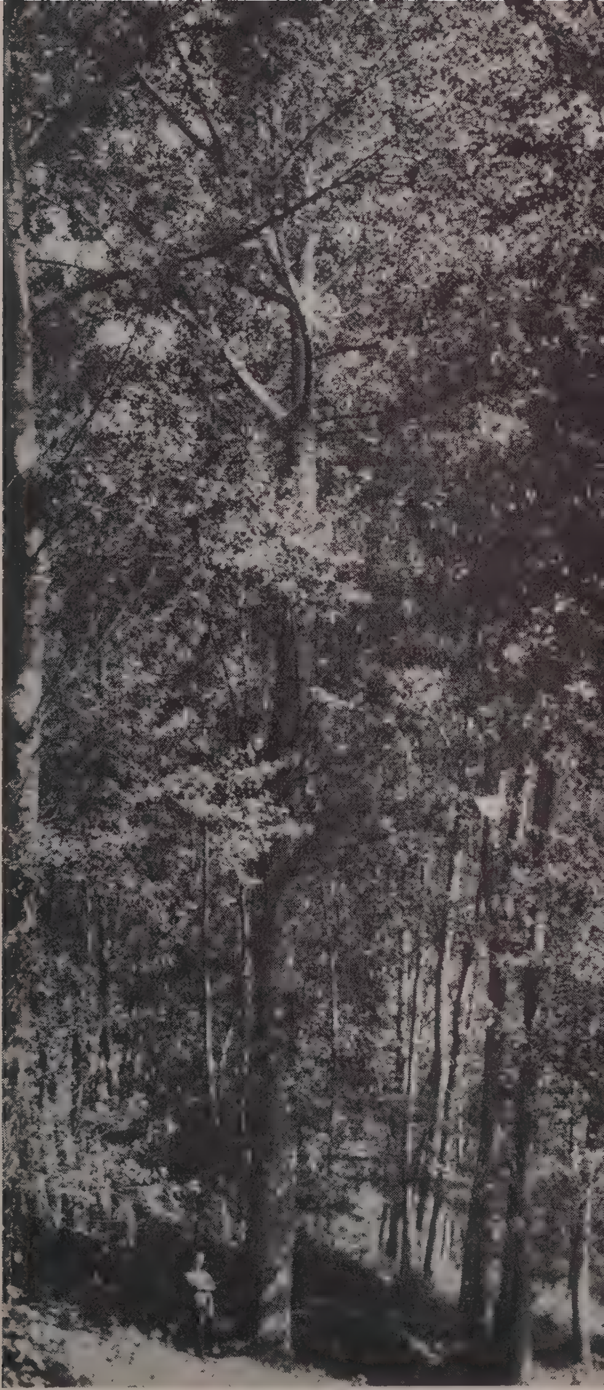
In the second case, the aim is to increase and improve the yield from natural poplar stands, pure or mixed, by sylvicultural practices, and of stands composed of other species by introducing carefully selected poplar types, to which sylvicultural methods are equally applicable. In this case the planter has less influence on the environment than in the case of intensive cultivation and therefore the choice of poplar best suited to the site is of fundamental importance.

---

[1] When there are several types selected for ecological, or more often for economic reasons, they are not mixed tree by tree but are juxtaposed by lines or groups. Polyclonal poplar cultivation, with progressive elimination of the poorer clones, is sometimes recommended but is more suited to the silvicultural treatment of forest species and cannot be applied here without experience over a long period.

FIGURE 38. – 20-year-old poplar from which original cuttings of the clone 'I-262' were taken, at Villafranca, Piedmont.

Courtesy
Istituto Casale Monferrato



There exists, of course, a whole range of transitional forms of cultivation between these two extremes, and in many cases, depending on the criterion adopted, poplar growing can belong to one or the other type.

The question of growing poplars outside or inside the forest is one with which the International Poplar Commission has been concerned since its creation, both in its working groups, and especially during tours in the field, and it is one which will remain on its work agenda for the future. Study of the problem involves the assembling of much practical data before it will be possible to draw up precise rules for each particular case. It has, therefore, been the aim of this chapter to establish, on the basis of methods which have proved their worth in certain regions, a set of general principles which are valid everywhere and from which the techniques suited to the varied conditions locally can be deduced. A separate section has been devoted to the two methods of cultivation, while the techniques of propagation, which are the same in both cases, will be dealt with at the beginning of this chapter.

1. METHODS OF PROPAGATION AND NURSERY PRACTICES

One of the principal characteristics of poplars is that they multiply in the vast majority of cases by a sexual or vegetative means, and it is, therefore, primarily this form of propagation which will be discussed here. However, sexual reproduction, that is to say by seed, is used not only in clone selection but also for the propagation of improved strains of species which do not root easily from cuttings, as is especially the case with aspens. Generally speaking, the plants are raised in a nursery, although stands are sometimes established by the direct rooting of cuttings.

A. Nursery practices

It is assumed that the establishment of a nursery shows a certain number of different qualities from those usually required in forest nurseries. The soil must be fertile, deep, fairly friable, not acid, naturally cool, capable of being watered or irrigated, and well manured, though not excessively, with organic materials. Preparation consists of deep ploughing, which must be done more thoroughly if the soil is heavy, and where the danger of dryness is greater. Where the soil is too compact, a dressing of a good organic manure is advisable. It is also beneficial, on the other hand, to soil which is too light. The quantity of well-rotted manure which should be used varies from 20 to 30 tons per hectare. Town sewage has a good effect on the growth rate.

Inorganic fertilizers, such as phosphates and potassium, improve lignification, whereas an excess of nitrogen can render the plant more vulnerable to attacks by fungal parasites, notably *Dothichiza.*

The following formula is fairly often used:

Superphosphate	600 to 1,000	kilograms per hectare
Ammonium sulphate	200 to 400	
Potassium salts	200 to 500	

Where possible, it is preferable to choose a site which is already under an agricultural crop rotation; if not, a rotation must be applied to the nursery, since it is not advisable to grow several successive crops of plants in the same section. In this rotation the poplars should, if feasible, follow a cleaning crop. Failing this, it is advisable to plough the site toward the end of the summer to counteract the invasion of weeds — one of the main obstacles to the good growth of young plants.

1. Propagation by stem cuttings

Cuttings consist of parts of one-year-old (very rarely 2-year-old) branches or stems.

Preparation of the cuttings

Origin

Cuttings can originate from:

a) fully mature shoots or epicormic shoots, which sprout from the trunk generally round the pruning scar, taken when the tree is pruned;

b) one-year-old shoots taken from stools treated as stumps or pollards;

c) side branches of plants which have been early pruned in the nursery;

d) surplus shoots, or shoots from the stems of plants cut back in the nursery, either transplanted (*barbatelles*) or rooted directly on the site;

e) one-year-old shoots cut from the crowns of vigorous young trees.

It is therefore necessary to use young material taken from healthy and vigorous trees or plants.

Since cuttings should clearly not be taken from diseased or suspect stock, in Italy and elsewhere the *barbatelle* nursery is preferred to the use of stools since it has the advantage, amongst others, that the best formed material can be selected and weak, defective or diseased material discarded.

The reproductive capacity necessary for vegetative propagation appears to decrease with the age of the stock from which cuttings are taken.

Both wood and buds must be well formed. When dividing a stem into cuttings, care must be taken to remove the apical portion, which is often too delicate and pithy. Cuttings mainly from terminal shoots and, to a lesser degree, from the base of the stem, often produce less vigorous plants than intermediate cuttings of equal thickness; they also give rise to more failures than the latter.

Thickness or diameter

It is generally agreed that pencil thickness is a good size, the minimum diameter being 8 millimeters and the optimum between 10 and 12 millimeters. Cuttings of this size are superior to thick cuttings, as a loss of vigor has been observed in cuttings of more than 20 millimeters in diameter. Because of this, when they have recourse to stools, some nurserymen prefer stumps 75 centimeters to 1 meter from the ground, which throw out finer shoots than those kept flush with the ground or very low. However, experiments carried out in France have shown that with poplar clones which root easily from cuttings (for example, *P. deltoides* cv. ' virginiana ') the thickness of the cutting and the part of the stem from which it is taken have no effect on its rooting capacity or on the future development of the plants.

When the diameter of the cutting exceeds 20 millimeters, the rooting capacity is lessened and, moreover, the plant which it produces is basically disproportionate and is less easily readjusted to the lower vigor of the plant.

As a general rule, therefore, when taking cuttings the base and the apex of shoots and stems should be rejected.

Length

The length of cuttings depends on the quality of the soil. If the soil is deep, fresh and fertile, in which the roots sprout and grow well, then shorter cuttings can be used. Where the soil is less fresh and fertile, or cannot be irrigated or watered, longer cuttings are necessary.

The length of cuttings generally varies between 18 and 22 centimeters. In certain cases it is as much as 30 to 40 centimeters and over. In extreme cases, one third or even half of the cutting is left above ground. This practice often has the disadvantage that a second operation is required; this consists of removing the tip which dries out.

In theory, it is possible to take cuttings having only a single bud, that is, very short, but special care is necessary if they are to survive, and this method should be adopted when only a small quantity of valuable material is available.

A special case is the long cutting or "whistle" (used in Belgium) which is from 75 centimeters to 1.50 meters long and includes the apex of the shoot *together with the terminal bud.* These cuttings will often have a too large elongation the first year. They can, moreover, only be used in conjunction with normal methods and are in any case exceptional.

Collection

The best procedure is to cut the shoots and stems to be used for cuttings just before it is intended to cut them up and insert them in the ground, that is to say, in the spring or at the end of the winter, just after the ground has thawed and before the growing season starts. Poplar growers everywhere, despite differences of climate, are in agreement on this point. Naturally, in countries where there is no fear of frost, cuttings can be taken for immediate planting throughout the dormant season.

The lapse of time between the cutting of the stool bed and insertion should always be as short as possible in order to increase the chances of establishment and reduce the possibility of attack by *Dothichiza.* However, for practical reasons, cuttings are often taken in late autumn or at the beginning of the winter, in which case they have to be stored. The cuttings are collected in bundles and heeled into tubs containing about 40 centimeters of sand. They are placed vertically, preferably with the point downward, on a layer of soil 5 to 10 centimeters deep. The tubs are put in a sheltered place away from the wind and sun in a soil which is not too moist. The cuttings are then covered with a 20-centimeter layer of sand overlaid with branches.

Taking cuttings

This is generally done with very sharp secateurs, since the cut must be clean and not bruised. A horizontal cut is the most usual and suitable.

Paraffin treatment and dyeing of cuttings

If cuttings have to undergo long journeys (15 days or more), or if storing conditions are inadequate, it is advisable to coat the tips with paraffin to prevent them from drying out. They may also at the same time be dyed with different colors to avoid confusion of the various types.

Insertion of the cuttings

Spacing

Spacing within the line and between lines varies considerably; it clearly depends partly on whether machinery will be used for cultivation work, but above all on the type of plants it is desired to raise and the technique to be followed.

When the cutting will not be transplanted after one growing season. In this case insertion is at final spacing, allowing the plant to remain in place.

The distance between cuttings in the line should not be less than 40 centimeters. The distance between lines can vary between 1 meter and 1.40 meters; it can be increased to 1.80 or even 2.20 meters if it is intended to use horse- or tractor-drawn technical cultivators.

The spacing is the same if it is intended to cut back the young plant at the end of the first year in order to produce fresh cuttings from the shoot removed and also to obtain a straighter stem.

When the cutting will be transplanted and cut back after one growing season. This technique at present in use in Italy, where the young one-year-old plants for transplanting are known as *barbatelles* and also in certain districts of France, allows much closer spacing and consequent economy in land and maintenance. The distance between cuttings can be as little as 20 centimeters, and even less in very sunny climates; the distance between the lines varies between 80 centimeters and 1 meter.

The young plants are cut back, leaving two or three buds above the collar of the stem and provide high quality cuttings. Many poplar growers consider them superior to those taken directly from the stools and less likely to transmit disease.

The *barbatelle* method is particularly suitable for poplar types with a very high growth rate and when the soil and climate increase their natural vigor. It enables the raising of stouter, less elongated plants, which are thus better equipped to resist windblow and windbreak. It also enables poor quality, damaged or weak plants to be eliminated at the time of transplanting, thus improving the state of health and quality

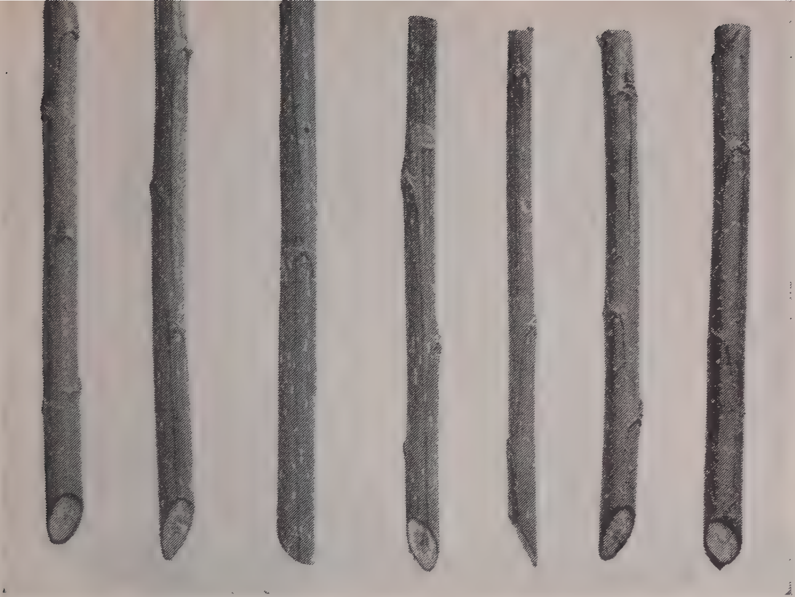


FIGURE 39. – Different types of cuttings.

FIGURE 40. – Inserting cuttings which will be cut back and transplanted after one year's growth (*barbatelles*).

Courtesy
Istituto Casale Monferrato

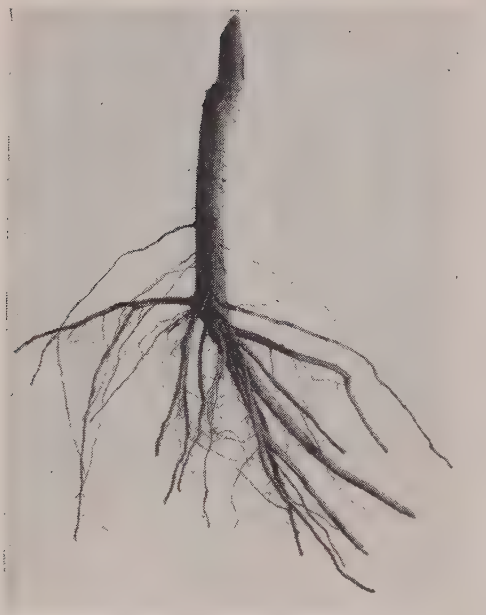


FIGURE 41. – Rooted cutting cut back (*barbatelles*) but not yet prepared for planting.

Courtesy *Istituto Casale Monferrato*

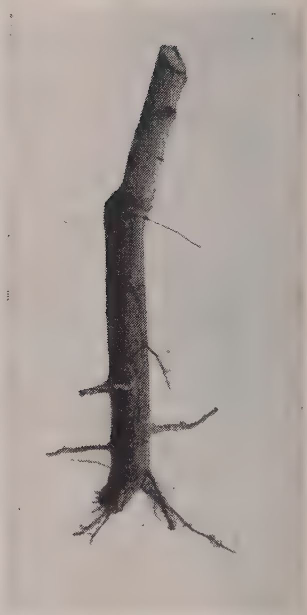


FIGURE 42. – Rooted cutting cut back (*barbatelles*), ready for planting.

Courtesy *Istituto Casale Monferrato*

of the produce. Finally, as has already been mentioned, cutting back improves the straightness of the stem, which is particularly important for certain clones.

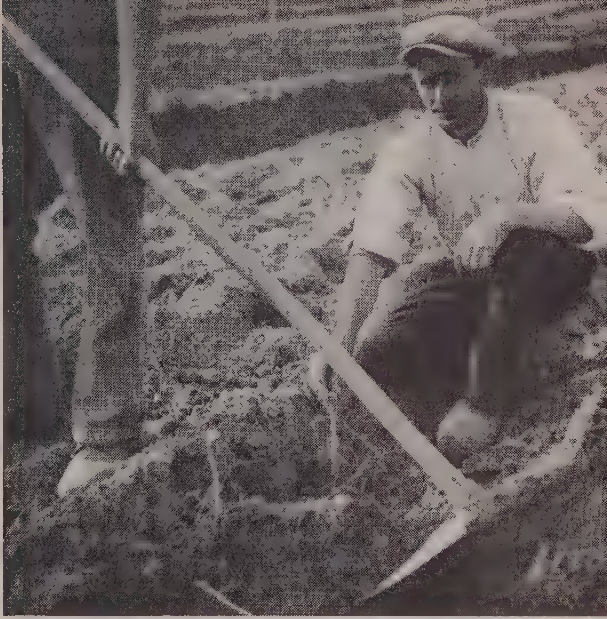
This method is not recommended for poplar types which have a slow initial growth rate, or where unfavorable soil and climatic conditions may cause harm to the young plant if it is transplanted.

The *barbatelles* which are lifted (roots trimmed and with several centimeters of stem) are planted at the beginning of the second year, with the final spacing as given for the previous methods, that is to say, 40 to 60 centimeters between plants and 1.80 meters to 2 meters between rows.

The two methods described above can be combined. Cuttings which are in denser rows than in the first method can be thinned by removing one in two plants at the end of the first year, cutting them back and transplanting them. Closely spaced cuttings intended to produce

FIGURE 43. – Establishing a nursery with *barbatelles*.

Courtesy
Istituto Casale Monferrato



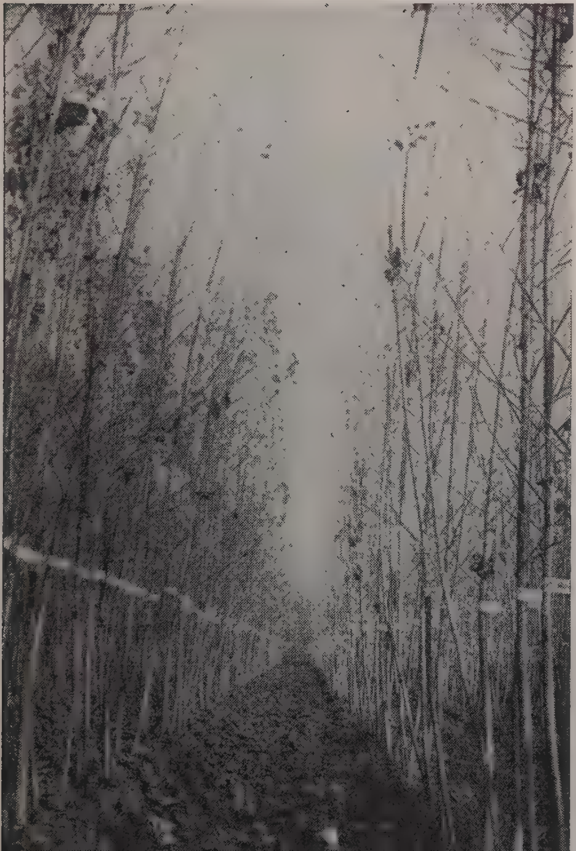


FIGURE 44. – A nursery of 2-year-old *P.* x *euramericana* 'I-214', bearing guarantee seals.

Courtesy *Istituto Casale Monferrato*

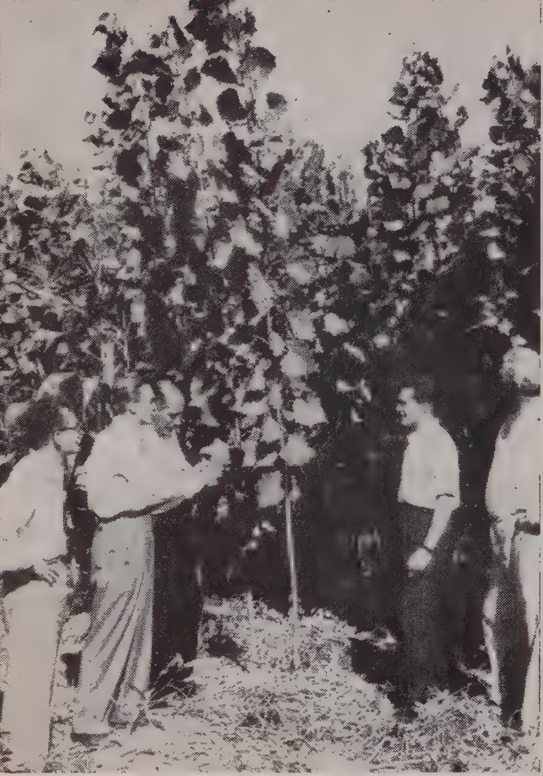
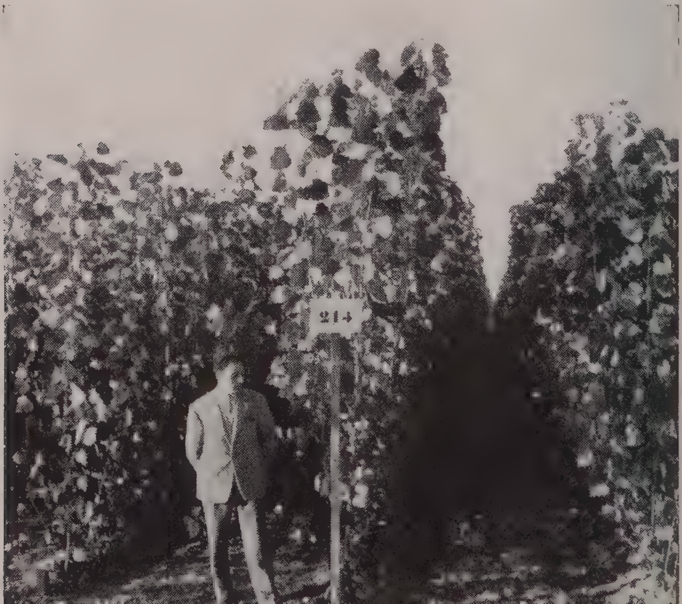


FIGURE 45. – A nursery of *P.* x *euramericana* ' I-214 ' in the Paranà delta, Chile, five months after planting.

Courtesy *E. Vaccarone*

FIGURE 46. – A nursery combined with a nursery of *barbatelles* of *P.* x *euramericana* ' I-214 ' at Marengo, Bergamo, Italy.

Courtesy *Istituto Casale Monferrato*



barbatelles can be placed between widely spaced rows consisting of permanently established cuttings (first method) or transplanted *barbatelles* (second method).

Preparation and insertion of cuttings

Before planting, cuttings are usually soaked in water for 24 to 48 hours. The advantage of this practice varies according to the type of poplar and the freshness of the material.

In the case of types more or less directly related to the southern strains of *Populus deltoides* spp. *angulata*, which has a highly developed pith. soaking for about ten days appears to increase appreciably the percentage of plants which survive.

Treatment with various substances to prevent damage by *Dothichiza* is only relatively successful. This is also the case with applications of root-promoting substances which, however, may be of some value to poplars of the *Leuce* section: the methods have yet to be specified.

The cutting is sunk vertically and directly into the soil, if this is loose and light, for it is important not to damage the young bark. The cuttings are often placed in rows of small, previously prepared trenches or furrows. This method is essential for planting *barbatelles*. It is always necessary, when closing the furrow, to fill in the earth with care, so that it adheres well to the cuttings or roots and no hollows are left which may be detrimental to rooting. Generally, the material is sunk into the ground, leaving at least one or two buds or " eyes " aboveground. In regions liable to extreme drought and where irrigation cannot be carried out, the cutting is sunk almost flush with the ground.

Maintenance

Cleaning

Cleaning is always necessary since weeds grow abundantly in the fresh, rich soil of the nursery, and offer strong competition to cuttings and young plants.

The cleaning, which is as beneficial as a second dressing of the ground, also helps to combat drought. It is indispensable when the cutting is just beginning to take root and its root system is as yet unable to resist competition from other plants.

Removal of surplus shoots

Cuttings, notably ones which have been cut back, may throw out several shoots; of these only one, the most vigorous and best placed, should be kept. This operation should not be carried out too soon, to avoid the risk of breaking or severing the retained shoot (which may not yet be sufficiently woody), either due to human action, animals or bad weather. The best time is considered to be when the shoots have reached a height of 30 to 35 centimeters.

Early pruning

This should be avoided the first year. During the second and third years it should only be carried out to remove double leaders or to restrict the excessive growth of a side shoot. These should simply be shortened, or, better still, the soft shoots nipped in time. In fact, the plants should always have the maximum number of leaf organs in order to produce strongest stems more rapidly. Care should be taken to avoid causing wounds through which parasites, particularly *Dothichiza*, can enter.

Marking

Marking should be done with different colors to distinguish plants suitable for lifting, stems to be cut back or side branches which will be used to produce cuttings, so as to avoid confusion when cuttings are taken and at the time of planting.

Protection against vegetable and animal parasites

Although this subject is dealt with fully in the following chapter, it is appropriate to say a few words here on the subject of protection against *Dothichiza*. First, it is advisable to avoid early pruning, if possible, and the wounds it causes. Chemical treatment applied at the right moment and repeated during the growing season is recommended — for example, spraying with copper or organic compounds. The best means of defense, however, is to apply cultivation methods which will give the maximum vigor to the plant.

Lifting and trimming the plants

These operations should be performed after the leaves have fallen.

Usually the plants are lifted by using a sharp-edged spade. However, in very large nurseries, in order to reduce the expense of this operation, which adds considerably to the production costs, it is advisable to plough on either side of the rows. Then with a very sharp hoe uproot the plants by cutting the roots cleanly underground. Another equally common practice is to lift the plants with a spade, turning them into a previously prepared furrow. Only roots which are too long are pruned. Lastly, in some nurseries special ploughs driven by a winch cable perform the operation speedily and accurately.

Whatever the method used, care should be taken to break the roots as little as possible and, above all, to avoid uprooting by pulling the plants roughly. On account of the handling, transport, etc., to which the plants are subjected, it is necessary partly to remove the side branches but this should not be done excessively. In Italy they are completely removed, the dry climate in general justifying such drastic pruning in order to balance the crown with the root system and to facilitate resumption of rooting. In addition, it is advisable not to prune too close to the stem; it is preferable to leave a *very small* stump which will reduce the wound and prevent to some extent the entry of parasites, particularly *Dothichiza.*

Origin and commercial category of plants supplied by nurseries

First, it is necessary to distinguish between *a*) plants originating from cuttings; and *b*) plants originating from *barbatelles.*

Plants originating from cuttings not cut back

At the end of a growing season, cuttings produce plants with one-year-old stems and roots. After a second growing season in the nursery they are known as " two-year plants " with two years' growth of roots and stem, and can be used at this age. At the end of the third growing season, after which it is not advisable to keep them in the nursery, they are called " three-year plants " with three years' growth of stem and roots.

Plants originating from barbatelles (or from cuttings cut back at one year)

At the end of the first year there is two years' growth of root and one year's growth of stem. After the second year, so-called " two-year-olds " have three-year-old roots and a two-year-old stem; at this point the plant is judged to be at its best and is sufficiently large for planting. Left longer than this it will be too big and is therefore only retained in the nursery in exceptional cases, when it will have four-year-old roots and a three-year-old stem.

The plants are not generally marketed according to age but are grouped into categories based on their circumference at 1 meter from the collar: plants of 8-10, 10-12, 12-14 or 14-16 centimeters. All plants of less than 8 centimeters in circumference and 2.50 meters in height should be rejected.

In Italy, on the other hand, the following trade classification is used for plants having *two-year-old stems*, which are those most preferred, whether they originate from cuttings or *barbatelles*:

a) plants with 8 to 11 centimeters in circumference at 1 meter aboveground;
b) plants with 12 to 15 centimeters in circumference at 1 meter aboveground;
c) plants with more than 15 centimeters in circumference at 1 meter aboveground.

On the basis of this classification it is estimated that a nursery normally yields the following percentages of plants (allowing for the rejection of 5 percent of imperfect, damaged or diseased plants):

30 percent of the plants in category *a*)
40 " of the plants in category *b*)
30 " of the plants in category *c*)

In France, control of the sale of poplar cuttings and plants is based on a government order of 31 October 1951, under which the age and dimension of plants must be specified.

Age. This is indicated by two or more figures, the first of which represents the number of years passed in the nursery as a seedling. For poplars which are not seed-propagated the first number is 0. The second figure represents the number of years (i. e., growing seasons) spent in the nursery since the cutting was inserted. If it has been transplanted, then a third figure is added to indicate the number of years in its third position.

Dimension. The length from the collar to the terminal bud must be specified in meters and, if necessary, the circumference in centimeters one meter above the collar.

Examples

0 - 1/ m./ 0.80: One-year-old plant originating from a cutting, 80 centimeters high.

0 - 3/ 3m./ 10 - 12: Plant originating from a cutting, has been in the ground for three years and measures 10 to 12 centimeters in circumference and 3 meters in height.

FIGURE 47. – A nursery of 2-year-old *P.* x *euramericana* ' I-455 '.

Courtesy *Istituto Casale Monferrato*

FIGURE 48. – Stoolbed nursery of *P.* x *euramericana* cv. ' gelrica ' belonging to the *Nederlandsche Heidemaatschappij* in the Netherlands.

Courtesy *R. G. Fontaine*

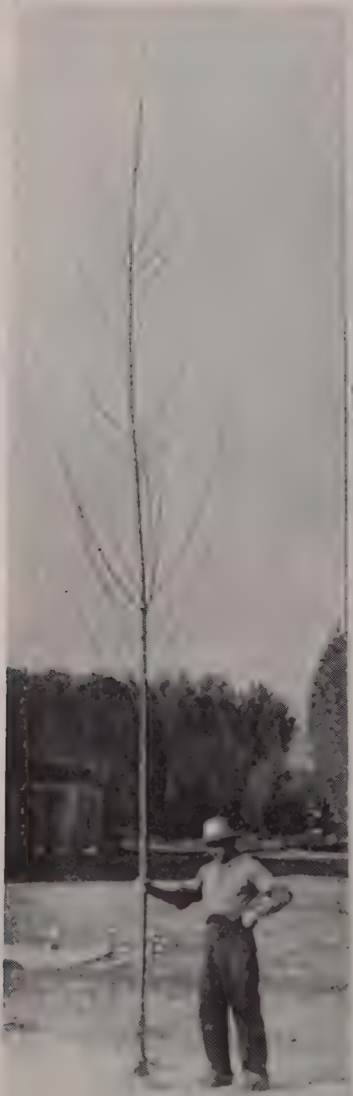


FIGURE 49. – 2-year-old poplar taken from the nursery and ready for planting.

Courtesy *Istituto Casale Monferrato*

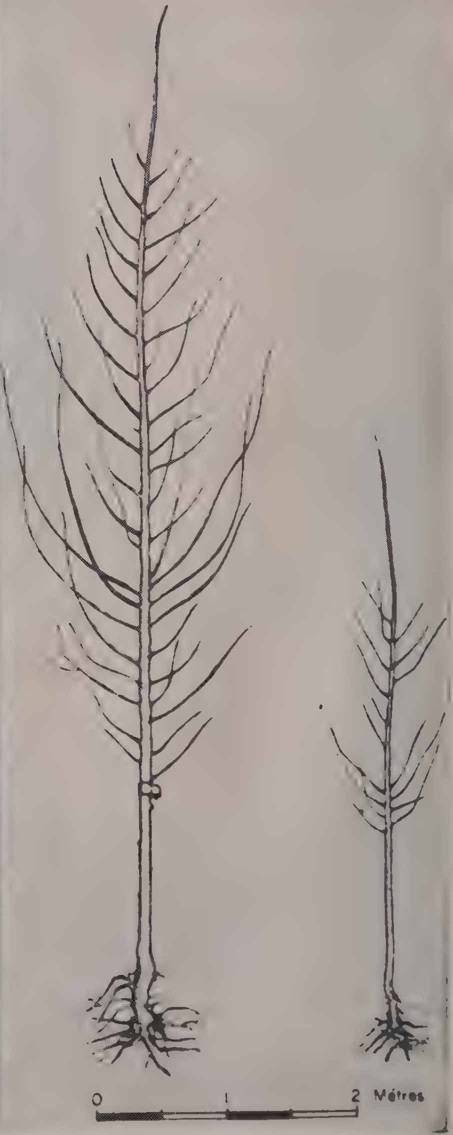


FIGURE 50. – Young poplars aged 2 and 1.

Courtesy *Herbignat*

0 - 1 - 3/ 3.50m./ 12 - 14: Four-year-old plant originating from a cutting, transplanted one year after being planted and having passed three years in its new position; measures 12 to 14 centimeters in circumference and 3.50 meters in height.

Stoolbed nursery for the production of cuttings

As in the case of other nurseries, the stool nursery must be in deep, fresh and fertile soil. Its purpose is to produce one-year-old shoots which can be divided into cuttings.

The stools themselves are two- or three-year-old plants which have been cut back at ground level or to a fixed height, and from then on are treated as pollards. The shoots they put out are removed annually when the wood is ripened, and are divided into cuttings, preferably just before it is intended they should be inserted.

The spacing between the stools varies from 40 centimeters to 1 meter in the row and from 80 centimeters to 1 meter between rows.

The height from the ground at which stumping is carried out also varies very widely. In France and the Netherlands the height is 10 to 20 centimeters. In Belgium some nurserymen prefer to cut 50 centimeters to 1 meter above the ground so as to obtain finer shoots. In the west and north of Germany the stump is frequently flush with the ground, whereas in the south the cutting is done at a height of 1 meter.

The stools should be renewed when the shoots show signs of loss of vigor. This is primarily a matter of observation. The care given to them, the spacing adopted and the manuring, all have a great influence on the life of the stool. In the Netherlands, they are generally renewed between five and eight years, in Germany at ten years. In Switzerland, the Commission for Poplar Cultivation has provided for the renewal of the stools every ten years, in the agreement made with the purchasers of selected propagatory stock. Care should be taken that the stools do not put out shoots which are too thick, from which good cuttings cannot be taken.

It is assumed that the degeneration of certain types of poplar may be due to the too frequent repetition of vegetative reproduction, and that in order to obtain plants of better regenerative capacity it is necessary to renew the original stock. Guided by observation the stock should be renewed at certain intervals, always with the most vigorous and disease-resistant types. Such renewal is essential when certain diseases become manifest.

2. PROPAGATION BY ROOT SUCKERS

This method of propagation is only used for species which sucker and which do not root from cuttings, particularly gray poplars and aspens. The young suckers are removed with a portion of root and are transplanted in a nursery for several years. Only a limited number of plants can be obtained by this method.

3. PROPAGATION BY SEED

The seeds ripen in early spring and should be sown immediately. This applies both to seeds collected from the tree as well as to those obtained from branches cut just before flowering, kept individually in vases and pollinated artificially, as will be discussed later with reference to breeding methods.

The cotton can be removed by rubbing or washing the seeds on a fine sieve, which will only let the seeds through; on the other hand, they can be sown together with the cotton.

With the first method it is much easier to obtain a uniform sowing of a very small seed.[2]

The seeds are sown in beds, frames or boxes filled with very fine earth or even sand mixed with a little peat; the ground is watered before sowing and should be kept moist until the seedlings are ready for lifting. They should be protected by a mulch or by glass. The seeds germinate in several days. If the sowing is dense they should be pricked out to a suitable spacing between each, immediately the seedlings have their first leaves. Spraying with a nutritive solution is highly beneficial at the beginning as there is serious risk of fungal diseases at this stage.

Seedlings can reach 50 centimeters or even 1 meter in height by the end of the first growing season. From then on the cultivation technique does not differ appreciably from that of plants obtained from cuttings.

In some regions, estate owners or nurserymen still make fairly frequent use of the abundant natural seeding which takes place on river banks, transplanting the seedlings in the nursery. These more or less complex populations have only a very relative value.

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[2] There are 4,000 to 8,000 clean seeds to the gram.

B. DIRECT PLANTING OF CUTTINGS OR PROPAGATION BY SETS

Instead of using rooted plants derived from cuttings or seeds after a varying length of time in the nursery, in cases where the ground is well watered and where rooting is consequently easy, direct planting of large cuttings or sets is sometimes practiced.

In western Europe this technique is generally used in very damp ground, where it is difficult to dig pits and where, conversely, it is easy to firm the cutting, by sinking it into the ground to a depth of 40 to 60 centimeters, the stem being tapered.

Sets are the stems of one-to-three-year-old plants produced from cuttings from which the roots have been removed. More often, however, they are branches 3 to 5 meters long and 16 to 20 centimeters in circumference, which are taken from pollards cut every four or five years, or from stumps cut on the same rotation. They may also be branches cut from the crowns of trees, or pruned branches (France - Poitou marsh). These branches are often of poor form.

At all events, branches or stems should not be used as sets if they are too old, since rooting capacity decreases with age; neither should they be too delicate and, in consequence, too fragile. Care should be taken to avoid taking sets from trees, pollards or stumps which are in poor or diseased condition, as this method of propagation can give rise to the easy and rapid spread of disease. Infected pith can frequently lead to the formation of much false heartwood or even to decay.

In the Near East, and in other regions where poplars are planted at very close spacing and irrigated, two methods are used: either the direct rooting of cuttings identical to those used in nurseries, or the use of sets of smaller dimensions than those described above. The latter are branches of 1.30 to 2 meters in length which are cut from young plants or trees at the time of pruning and are planted in the ground direct.

II. INTENSIVE POPLAR CULTIVATION

Poplar growing as defined earlier is essentially an intensive form of cultivation, and is generally associated to a varying degree with different forms of agriculture. A distinction is made between poplar plantations or stands and border or line plantings. The cultivation of poplar in lines is of considerable importance because of the innumerable ways in which it can be combined with agriculture. Between these two types of cultivation is to be found a whole range of transitional types, in particular cultivation in groups, which is ideally suited to the small peasant land holding.

Before discussing and analyzing the different elements of these two types of cultivation, the growth increment that can be obtained, as well as the economic aspects of the problem, a number of points can be made about the choice of poplar types and the choice of site.

Choice of types

The choice of types is closely linked to local conditions, and in most cases planters will select those described in the preceding chapter which, according to present knowledge, give the most satisfactory results and yield the best produce.

These types belong almost invariably to the *Aigeiros* section, and are, therefore, chiefly black poplars. However, sometimes white poplars, balsams, etc., will find a place, at least locally, in poplar cultivation.

Choice of site

The poplar is an exacting plant, and if vigorous and rapid growth is to be obtained as well as good quality timber, it must be grown in favorable conditions. Generally, the soil requirements are more or less similar for all types of poplar with a high increment rate. In order to thrive they all need a soil which is fertile, deep, workable, aerated and well supplied with water. They all react unfavorably to excessive soil acidity.

Therefore, the three essential soil factors which determine the success of poplars are:

1. good aeration, allowing the roots to breathe freely;
2. good water supply; and
3. adequate mineral content.

Aeration

The poplar is averse to stagnant water, which causes asphyxia of the roots; therefore, it cannot be grown in soils where the water table is high. On the other hand, it stands temporary saturation of the soil fairly well, provided the water is cold, constantly renewed, and rich in dissolved oxygen alluvial with moving water. It does not suffer any harmful effects from winter flooding. However, during the growing season the level of the water table should not rise to more than 50 or 60 centimeters from the soil surface. If the water table is always near the surface, mount planting is recommended. This is the case with most peaty soils.

Water supply

This problem naturally arises for the most part during long periods of drought, and two distinct cases can be distinguished, depending on whether or not a permanent high water table exists.

First case: where a permanent water table does not exist, or where it falls several meters during the dry season, so that the poplar can no longer receive its water supply by capillary action. In this case, on account of its high water requirements, the cultivated poplar will only thrive in very deep soils, which are highly water-retentive and so rich in colloids, but nevertheses open and of good structure in which the roots can penetrate deeply. Conversely, soils which are compact, with a high clay content but structureless (generally showing traces of compression, " marmorosis " of the profile), are quite unsuitable. The roots are unable to penetrate and, owing to the lack of permeability, summer rain cannot penetrate and is lost through evaporation. Such soils are thus very dry in summer.

Second case: where a permanent water table exists. The water level must be sufficiently high in summer (2 or 3 meters) to continue to nourish the tree by capillarity.[3] This is the case with most poplar stands growing on alluvial soils of recent origin. It is necessary to emphasize in this respect the danger of layers of gravel which interrupt the capillary rise of the water and into which the poplar roots do not usually penetrate. In principle, the thickness of the gravel layer should not be more than 30 or 40 centimeters above the lowest level of the water table. However, if the absorption of subsoil water through the capillaries is only interrupted for a short period, a form of compensation can take place if there is a thick layer of fine earth on top of the layer of gravel. This then approximates to the preceding case, in which the tree, fed by the water reserves stored by the capillaries, can continue to live, with only a falling off in its rate of growth.

Mineral content

Soils suitable for poplars are those with a high absorptive capacity and a high base exchange capacity, that is to say, not excessively acid. Optimum conditions are where the pH is between 6 and 7. If it drops below 5, liming is advisable.

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[3] It may be noted, for example, that the maximum height of capillary action from a water table is about 1 meter in a silty soil.

To sum up, sites to be avoided are those with soils which are too compact or clayey; sites with stagnant water which cannot be drained; sites without sufficient depth of soil, or which, although deep enough, possess horizons unfavorable to capillary rise; rocky sites, and finally, dry sites which cannot be irrigated.

When the water table is too high, mound planting will alleviate the conditions to a certain extent. In peaty soil, if the peat layer is superficial, it is advisable to mix it in with the underlying soil layers. If it is thick, it will need to be worked for a period before planting in order to aerate and promote a certain amount of decomposition. It should be noted, however, that a layer of pure peat which is too thick can constitute an obstacle to poplar cultivation, especially if it dries out in the summer.

However, in very hot climates, as for example the Po Valley or the Paraná delta, excellent results are obtained despite the high degree of acidity, even without turning over to any depth the thick layers of peat.

A. CULTIVATION OF POPLAR IN STANDS

ARRANGEMENT AND SPACING

The spacing to adopt in poplar plantations is the next most important question after choosing poplar types which are resistant to disease and best suited to the ecological conditions of a particular site. The spacing determines the cultivation methods, felling age, and above all the quantity, quality and value of the timber yield. In fact, the whole future of the plantation depends on it. The spacing varies according to the characteristics of the types planted, the purpose of cultivation or the economy of the country and its site conditions (soil and climate). These are some of the reasons for the wide range of spacing to be found.

The question of spacing has certainly given rise to much discussion between poplar growers in all countries but a common meeting ground can be found if the problem is viewed from two aspects: physiological and economic.

Nature has shown the poplar to be an individualist. Natural poplar stands are always open, for it is a tree which needs adequate growing space. This is the physiological factor which should be borne in mind.

Dense plantations should be exploited at ages which are in inverse proportion to their density, that is to say, the more crowded they are the earlier they should be felled, relatively speaking, for the plantation cannot defy the physiological laws which govern it. Early felling will only yield small-sized timber and, if this has not sufficient market value, the plantation is not an economic proposition. Plantations which are moderately dense can produce more valuable timber, although still only giving a limited range of produce classes.

On the contrary, plantations with wide spacing produce an extensive range of produce, for plywood, sawing, packing cases, the manufacture of matches and for paper pulp. In fact, a range of produce for which the demand varies but the most in demand being those products requiring a high proportion of large-sized timber.

However, a dense plantation is more productive quantitatively in its early years than a more widely spaced stand of the same age; but after a *certain age limit*, which varies according to site conditions, the reverse is true, and the more widely spaced stand yields more timber.

A brief survey of the principal countries in which poplars are planted shows that they can be grouped into two quite distinct categories:

1. countries in which nearly all plantations have an initial density rarely exceeding 500 stems per hectare and with 1,000 stems only in exceptional cases (3×3 meters);
2. countries with very dense plantations, where the initial figure of 1,000 stems per hectare is always considerably exceeded.

Some typical examples have been chosen from different countries where poplar growing plays an important part and where the question of spacing has been given much attention.

Countries with averagely dense, or not very dense, plantations [4]

These are generally sited in western European countries.

In *Germany*, where intensive cultivation is less common than extensive cultivation, sometimes very close spacing is adopted:

a) in the Valleys of the Isar and the Danube, until 1950, poplars were planted at a spacing of 3×3 meters. The following observations were made on a 13-year-old plantation:

- *i*) number of stems to the hectare (1,116 — 3×3 meters);
- *ii*) number of trees surviving at 13 years: 616, of which 80 had not reached the minimum utilizable diameter (9 centimeters) for use as pulpwood;

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[4] Stands with a spacing of less than 4 meters (0.50 to 4 meters) in all directions can be regarded as *very dense;* those with a spacing of 5 to 7 meters *averagely dense;* and those of over 7 meters as *very widely spaced.*

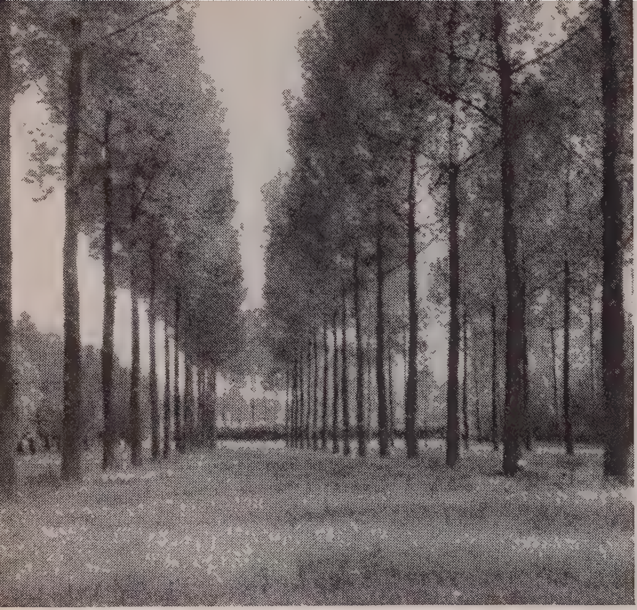
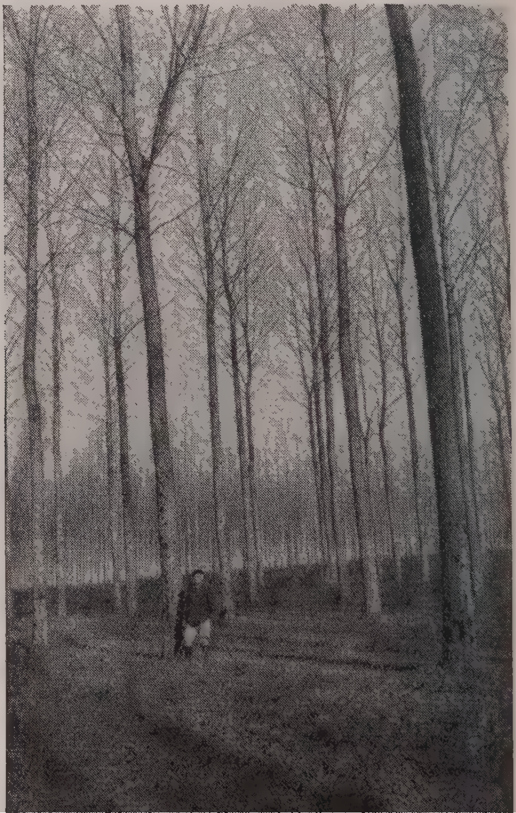


FIGURE 51. – Plantation of *P.* x *euramericana* cv. 'serotina' planted at wide spacing on grassland at Tongres, Belgium.

Courtesy *de Renesse*

FIGURE 52. – A 25-year-old poplar stand at wide spacing on pastureland in the Adour Valley, France.

Courtesy *J. Pourtet*



iii) number of trees virtually unusable: 580, of which 500 were removed as dead wood.

Half of the trees, therefore, brought no profit to the owner. The tendency now is to plant at 4.50 × 4.50 meters, and trials are being made with even wider spacings up to a maximum of 7 × 7 meters;

b) In the lignite basin in the vicinity of Cologne, where in the last 25 years poplar has proved to be the most suitable species for rehabilitating the spoil soil after extraction of lignite and preparing it for cultivation again, the law prescribes a spacing of 3 × 3 meters to be thinned when the timber is of utilizable dimensions.

In *Belgium.* Plantations of the *Union allumettière* (match industry) at Grammont provide the following data: in the course of the past 18 years there have been several modifications in planting practices: in 1931 and 1932 a very narrow spacing of 3.50 and 4 meters was used; from 1933 to 1942 spacing was increased to 5.50 and 6 meters; while from 1943 to 1946 there was a return to narrow spacing, using exclusively *P.* ' robusta '. Finally, in 1947, a 7 × 7 - meter spacing was adopted for pure stands of this variety. From the data obtained from the different sample plots the spacing has been fixed at 7 × 7 meters since 1947.

In fact, the few rare experiments with a spacing of less than 5 meters are regarded as unsatisfactory. The tendency is to adopt as the desirable minimum a spacing of 8 meters in all directions. The plantation with a spacing of more than 7 meters is more reliable and gives greater freedom of action to the forester. Actually, if at the age of between 20 and 25 years there is no market for the classes of timber which the stand can yield at that particular moment, it can be delayed until a more suitable moment. At wider spacings the trees remain in physiologically good condition and timber production can continue normally, increasing in quantity, quality and value. Plantations with a spacing of 6 × 6 meters or 7 × 7 meters are feasible where the object is to produce small- and medium-sized timber for felling at the age of 20 to 25 years, according to soil conditions. It sometimes happens that such plantations require premature and unproductive thinning.

In *France*, in the past 30 years, planters in certain regions have adopted the wrong methods in dense stands of *P* ' robusta ' (4 × 4 meters or 5 × 5 meters). The following example shows the economic disadvantages of such practices.

Timber yield after 26 years amounted to 193 cubic meters at a value of 600,000 French francs (US $1,750) in a plot of 400 standing trees, and

300 cubic meters at a value of 1,050,000 French francs (US $3,000) in a plot of 202 trees. The increase in the actual value of the timber does not depend solely on the quantitative increase of material but on the higher percentage of the more valuable classes of produce.

TABLE 3. - COMPARATIVE YIELDS OF TWO POPLAR STANDS WITH SPACINGS OF 5 × 5 METERS AND 7 × 7 METERS

Source: Guillaumin

26-year-old *P.* x *euramericana* ‘robusta’ — Valley of the River Oise

		5 x 5	7 x 7
Number of stems	at planting	400	202
	at felling	290	195
	percentage waste (trees disappeared or worthless)	28 %	3.5 %
Average circumference in meters		1.00	1.34
Volume at felling in m³	total	193	300
	unit volume	0.66	1.53
	annual production	7.7	12
	veneer logs	1.5	37
	percent	0.8 %	12 %
	sawlogs	54	202
	percent	28 %	67 %
	wood for packing cases	123	53
	percent	64.2 %	18 %
	paper pulpwood	13.5	8
	percent	7 %	3 %
Percentage of products with a higher value than the average price of the assortments		29 %	79 %
Value in French francs		600 000	1 050 000
Estimated expenses at actual costs	of planting	80 000	40 000
	of maintenance	—	105 000

As a result, the *Fonds forestier national* (National Forestry Fund), on the advice of the National Poplar Commission, at present only grants subsidies for plantations with a minimum spacing of 6×6 meters or 7×7 meters, which corresponds to a density of 200 or 250 stems to the hectare. Many experienced forest landowners considered it worth while to plant at an even greater distance — 8×8 or 9×9 meters.

In *Switzerland*, the *Communauté de travail* recommends a minimum spacing of 7×7 meters.

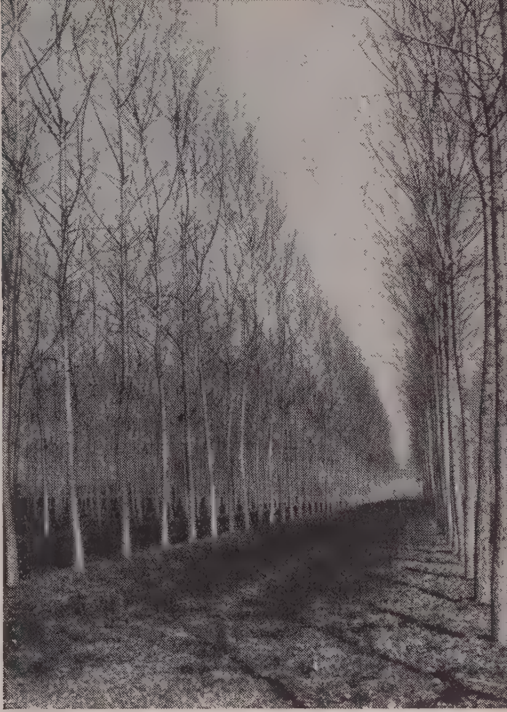


FIGURE 53. – A plantation of 5-year-old *P.* x *euramericana* ' I-214 ' in the region of Casale Monferrato. On the right, some specimens of cv. ' carolin '.

Courtesy *Istituto Casale Monferrato*

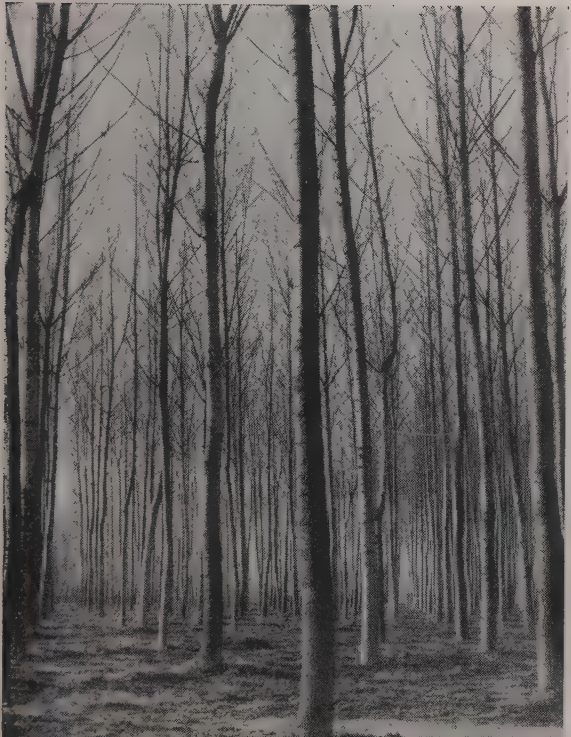


FIGURE 54.--9-year-old poplars in the region of Casale Monferrato.

Courtesy *Istituto Casale Monferrato*

TABLE 4. – INCREMENT PER HECTARE OF AN EVEN-AGED POPLAR STAND COMPOSED OF A MIXTURE OF EURAMERICAN HYBRIDS ON GOOD ALLUVIAL SOIL IN THE RIVER PO VALLEY, REGION OF CASALE

Age in years	Average diameter at 1.30 m. from ground		Total height of trees		Volume of standing timber per ha. (min. diameter 10 cm.)		Increment				Produce classes						Over-all estimate of the produce classes per hectare (loaded for transport from the felling site) Current price, January 1954					
							Annual	Average	Annual	Average												
	Density (stems per ha.)										Density 400 stems per ha.			Density 250 stems per ha.			Density 400 stems per ha.			Density 250 stems per ha.		
	400	250	400	250	400	250	400		250		Pulpwood %	Sawlogs %	Plywood %	Pulpwood %	Sawlogs %	Plywood %	Lire	Annual rate	Average rate	Lire	Annual rate	Average rate
	cm.	cm.	m.	m.	m³	m³	%	%	%	%												
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1																						
2																						
3																						
4	18.0	19.0	17.0	16.0	55.0	40.0	—	24.9	—	25.0	100	—	—	100	—	—	421 000	—	25.0	306 000	—	25
5	20.5	22.0	19.5	18.5	74.0	57.0	34.5	20.0	42.5	20.0	100	—	—	90	10	—	566 000	34.4	20.0	450 000	47.1	20
6	22.4	25.0	21.5	21.0	95.0	77.0	28.4	16.7	35.1	16.6	80	20	—	65	35	—	775 000	36.9	16.7	658 000	46.2	16.7
7	23.8	27.5	23.0	23.0	118.0	100.5	24.2	14.3	30.5	14.2	70	30	—	50	40	10	993 000	28.1	14.3	939 000	42.7	14.3
8	25.4	29.5	24.5	24.5	144.0	128.0	22.0	12.5	26.8	12.5	55	40	5	40	46	14	1 298 000	30.7	12.5	1 252 000	33.3	12.5
9	27.0	32.0	26.0	26.5	173.0	159.0	20.1	11.1	24.2	11.1	40	52	8	30	52	18	1 647 000	26.9	11.1	1 622 000	29.6	11.1
10	28.5	34.5	27.5	28.0	205.0	194.0	18.5	10.0	22.0	10.0	30	56	14	25	53	22	2 056 000	24.8	10.0	2 037 000	25.6	10.0
11	29.8	36.5	28.5	29.2	240.0	235.0	17.1	9.1	21.1	9.1	25	57	18	22	53	25	2 478 000	20.5	9.1	2 515 000	23.5	9.1
12[1]	31.2	38.5	29.4	30.2	[1] 277.5	[1] 280.0	15.6	8.4	19.6	8.3	20	59	21	20	52	28	2 937 000	18.5	8.3	3 046 000	21.1	8.3
13	32.3	40.2	30.2	31.5	314.5	328.0	13.3	7.7	17.1	7.7	20	56	24	20	49	31	3 368 000	14.7	7.7	3 610 000	18.5	7.7
14	33.3	42.0	31.0	32.2	350.5	378.0	11.4	7.1	15.2	7.1	20	54	26	20	47	33	3 784 000	12.4	7.7	4 192 000	16.1	7.1
15	34.2	43.8	31.8	33.0	385.0	429.0	9.8	6.7	13.5	6.7	20	52	28	20	45	35	4 189 000	10.7	6.1	4 795 000	14.4	6.7
16	35.1	45.5	32.4	33.5	418.0	481.0	8.6	6.3	12.1	6.2	20	50	30	20	43	37	4 584 000	9.4	6.3	5 418 000	13.0	6.3
17	36.0	47.0	32.8	33.8	450.0	532.0	7.6	5.9	10.6	5.9	20	48	32	20	41	39	4 973 000	8.5	5.9	6 037 000	11.4	5.9
18	36.8	48.5	33.0	34.0	480.5	582.0	6.8	5.5	9.4	5.5	20	47	33	20	40	40	5 330 000	7.2	5.6	6 629 000	9.8	5.6
19	37.5	49.7	33.1	34.1	509.5	630.0	6.0	5.3	8.2	5.3	20	46	34	20	38.5	41.5	5 674 000	6.5	5.3	7 216 000	8.9	5.3
20	38.2	51.0	33.2	34.2	537.0	676.0	5.4	5.0	7.3	5.0	20	45	35	20	37	43	6 003 000	5.8	5.0	7 785 000	7.9	5.0
21	38.9	52.5	33.3	34.3	563.0	720.0	4.8	4.8	6.5	4.8	20	44	36	20	35	45	6 317 000	5.2	4.8	8 354 000	7.3	4.8
22	39.5	53.8	33.4	34.3	587.0	762.0	4.9	4.5	5.8	4.5	20	43	37	20	33	47	6 611 000	4.7	4.5	8 906 000	6.6	4.5
23	40.1	55.3	33.4	34.4	609.0	802.0	3.7	4.3	5.2	4.3	20	41,5	38,5	20	30.5	49.5	6 898 000	4.3	4.3	9 459 000	6.2	4.4
24	40.5	56.5	33.5	34.5	630.0	840.0	3.4	4.2	4.7	4.2	20	40	40	20	28	52	7 175 000	4.0	4.2	9 996 000	5.7	4.2
25	41.0	57.5	33.5	34.5	650.0	876·0	3.2	4.0	4.3	4.0	20	38	42	20	25	55	7 459 000	4.0	4.0	10 536 000	5.4	4.0

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[1] Note the reversal of the production trend at the twelfth year: after then the increment of the more open stand begins to gain over that of the denser stand.

In *Italy*, at the *Istituto di Casale Monferrato* (Poplar Research Station), there is a tendency to stop planting in widely spaced lines of 10 meters, the trees being 3.50 meters apart in the line forming a quincunx of 6.50×7 meters or 7×7.50 meters. Plantations at closer spacing have proved much less profitable economically, as the following example shows.

Valley of the River Po: a mixture of Euramerican clones known by the collective name of "Canadian" poplars, that is, natural hybrids of *P. nigra* and *P. deltoides*. One plot had 400 standing trees to the hectare (5×5 meter spacing or 25 square meters per tree), and the other 250 trees to the hectare (5×8 meters spacing or 40 square meters per tree). The following conclusions can be drawn from Table 4:

a) from the first to the tenth year the highest total volume of timber corresponds to the greatest density, but after ten years the cubic content in both cases is approximately 200 cubic meters per hectare;

b) at the twelfth year, the cubic content of the plot with 250 stems appreciably exceeds that of the 400-stem plot;

c) at the fifteenth year, that is, in the space of five years, in the less dense of the two stands, the timber content is more than double what it was at the age of ten years;

d) at the eighteenth year, or only three years later, the cubic content is three times what it was at the age of ten years;

e) trees from the dense stand (400 stems) yield smaller produce than those of the less dense stand (250 stems) and consequently yield a much lower percentage of timber for plywood — only 33 percent as opposed to more than 40 percent.

After the age limit, or when the growth rate is reversed, in this case after 12 years, timber production increases not only in quantity but also in quality, and hence in revenue, as can be seen from the following data taken from the same two stands. These data enable the value of timber production per hectare, loaded for transport from the felling site, to be estimated as follows:

The stand with 250 trees yields:

i)	(after 10 years)	194 cubic meters, worth 2,037,000 Italian lire (U.S. $3,260);
ii)	(after 15 years)	429 cubic meters, worth 4,795.000 Italian lire (U.S. $7,660);
iii)	(after 18 years)	582 cubic meters, worth 6,629,000 Italian lire (U.S. $10,600).

In effect, this represents an increase in revenue of 1:2.4 over a period of five years (from 10 to 15 years) and of 1:3.3 over eight years (from 10 to 18 years).

To carry the comparison still further, it has been proved that the revenue derived from a 1-hectare stand of 250 trees felled at the age of 18 years far exceeds that derived from a hectare stand of 400 trees with two successive fellings at the age of 9 years. This is shown by the following figures which represent a cautious estimate. The stand with 400 trees clear-felled after 9 years produces 173 cubic meters valued at 1,647,000 lire, and gives a similar yield at a second felling after a further 9 years.

The first revenue obtained after 9 years and capitalized at 6 percent, from 9 to 18 years, gives a total of 2,782,000 lire. Thus, after 18 years the two successive fellings will have yielded a total revenue of 1,647,000+ +2,782,000=4,429,000 lire. At the same age the stand with 250 trees would yield 582 cubic meters of timber at a value of 6,629,000 lire, that is to say, a 50 percent higher revenue.

Countries with dense plantations

These are principally countries with a Mediterranean climate where poplar growing is nearly always associated with irrigation and agriculture.

In *Argentina*, the usual spacing is 2×2 meters and stands are clear-felled without an intermediate thinning. At the age of 5 or 6 years the young trees attain on the average a diameter of 18 to 25 centimeters at breast height. The timber is sold by the linear meter and the bole is used, to a minimum diameter of 3 to 4 centimeters, for packing cases and paper pulp.

In *Syria*, and to a lesser degree the *Lebanon*, plantations are nearly always irrigated and very closely spaced, 50 to 70 centimeters in the rows and with 1 meter to 1.50 meters between rows; a rather high mortality rate is reported at first (30 to 40 percent). After five years a first thinning is carried out and 30 to 40 percent of the stems are generally removed. This first yield supplies the artisan chair industry and provides billets for the construction of ceilings. Subsequent thinnings are governed by market needs. ‘ Hamoui ’ poplars are felled at between 10 and 20 years and ‘ Roumi ’ poplars between 20 and 40 years.

In *Iraq*, poplars are grown by irrigation in very crowded conditions with a spacing of 25 to 30 centimeters between trees and 1.60 meters between rows. Cuttings 30 to 50 centimeters in height are taken and rooted directly on the site; they grow rapidly. The rows are not thinned

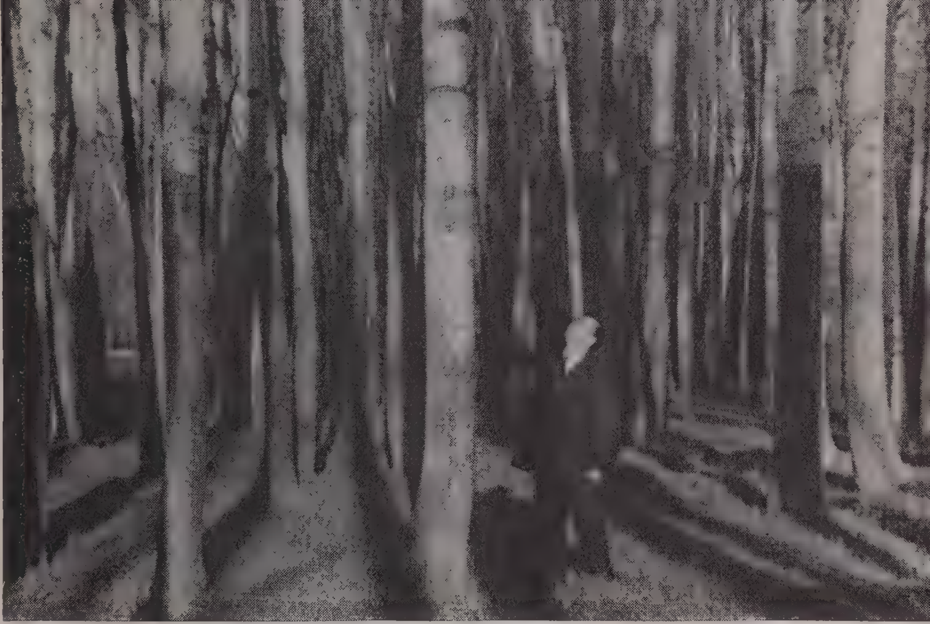
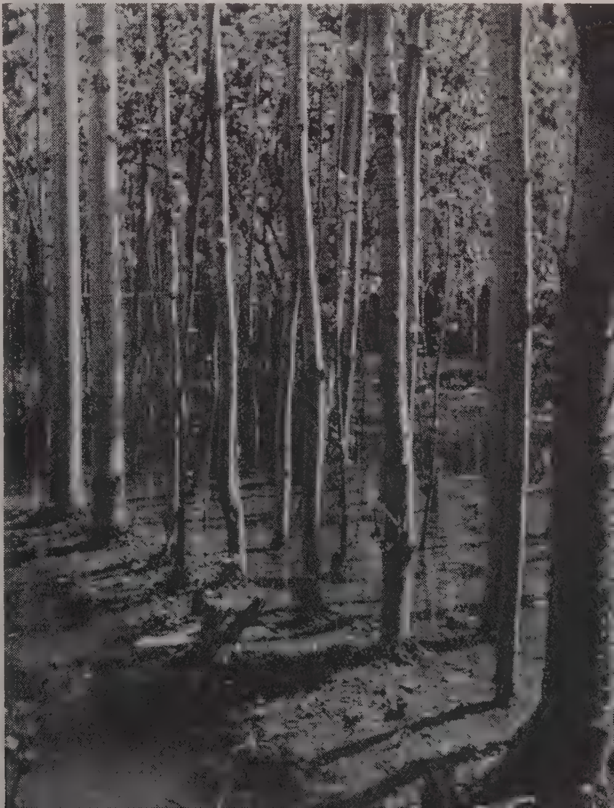


FIGURE 55. – Plantation of 25-year-old *P. alba* cv. 'Roumi' in the *ghouta* of Damascus, Syria.

Courtesy *van Bottenburg*

FIGURE 56. – Irrigated plantation of *P. nigra* cv. 'Hamoui' in the Valley of Barada, Syria.

Courtesy *J. Pourtet*



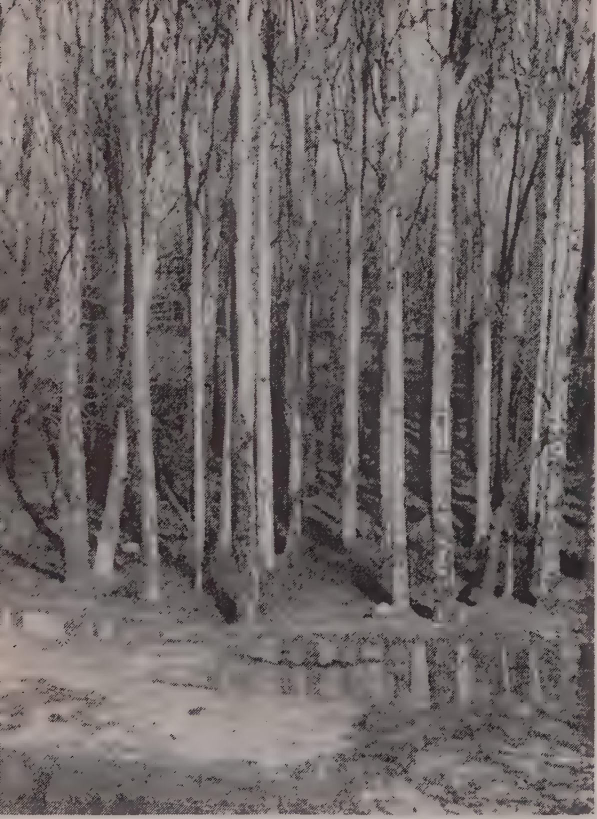
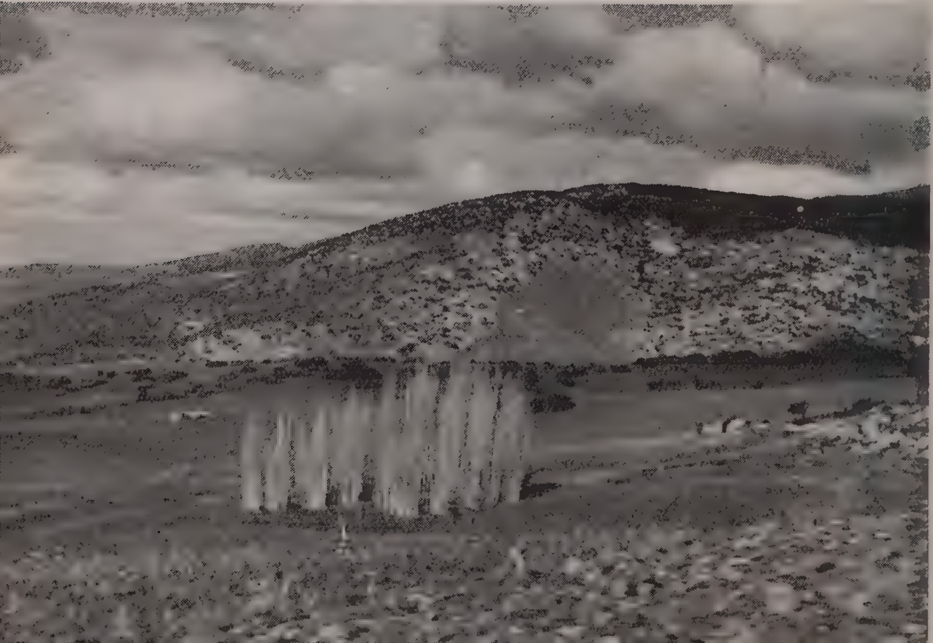


FIGURE 57. – Plantation of *P. alba* cv. ' Roumi ' at Chtaura, Lebanon.

Courtesy *R. G. Fontaine*

FIGURE 58. – Dense plantation of *P. nigra* cv. ' Hamoui ' in the Kur Dagh, Syria.

Courtesy *R. G. Fontaine*



until the trees are 8 years old, when a selective thinning is carried out; the remaining trees are clear-felled at between 12 to 15 years. Plantations starting at a density of between 4,000 and 5,000 stems to the *dönüm* (¼ hectare) contain 1,200 to 2,000 stems at the time of felling. The rate of growth varies according to the site but generally trees reach diameters of 20 to 22 centimeters at breast height by the age of 12 to 15 years. Trees are not allowed to grow to greater dimensions because the necessary felling equipment is not available and the means of transport are primitive. In the most important poplar-growing centers average annual increments of 40 cubic meters per hectare are reported.

In *Greece*, plantations on favorable sites frequently have a spacing of 2×2 meters and, on less favorable sites, 3×3 or 4×4 meters.

In southern *Spain*, for example in Andalusia, a spacing of 1.80 to 2 meters in all directions is often used on an 11-to-13-year rotation with intermediate thinning. In the more northerly province of Gerona, on the other hand, a spacing of 3 to 5 meters is customary for plantations of black and Euramerican poplars.

Plantations established by the State Forest Service, in particular those on the banks of the River Ebro, have a spacing of 4 meters in all directions.

In *Yugoslavia, Aigeiros* poplars — either *P. nigra* or some of the Euramerican hybrids — are frequently planted in some of the northern valleys in mixture with other species at a density of 2,000 plants to the hectare but results have been very poor. It has been clearly shown in a recent study on the very dense plantations of the Darda Inspectorate Valley of the River Drava that there are exceptional opportunities for poplar growing on this soil but that plantations with a spacing of 2×2 meters are a failure.

In the south of the country failures are less marked since the types planted are straight, fastigiate forms of *P. nigra*.

From these examples it can be seen that very dense plantations are characteristic of countries with a hot climate, where the sunlight is strong, where irrigation of poplars is the general rule and fastigiate strains are grown. In addition, very short rotations, rarely exceeding 15 years, are adopted. This explains, at least partially, why they are not a failure from the physiological point of view. These countries are poor in timber, and thinnings, even in the early years of the stand, yield valuable material. Propagation is usually by means of cuttings and sets which are cheap to establish.

Yugoslavia, an intermediate country, shows by the example quoted above, the failure of poplars with spreading crowns in a less southerly

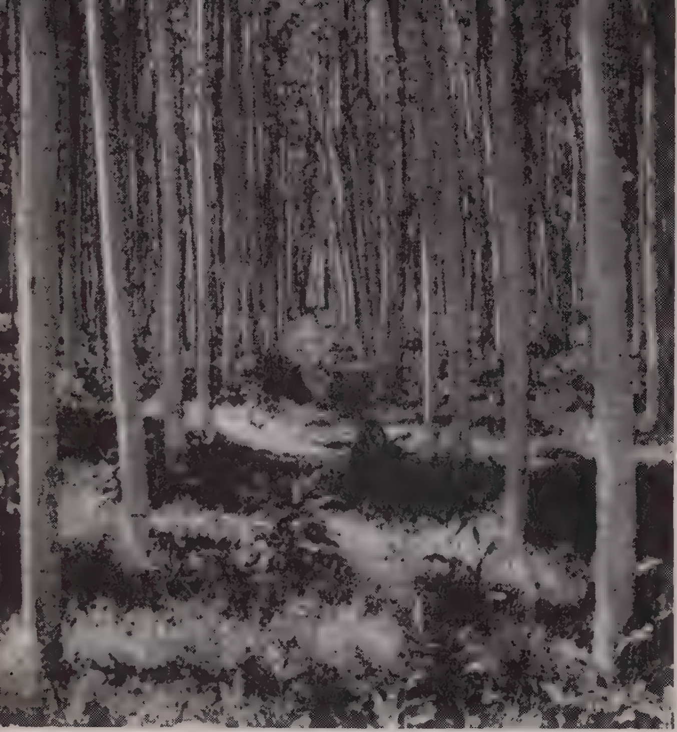
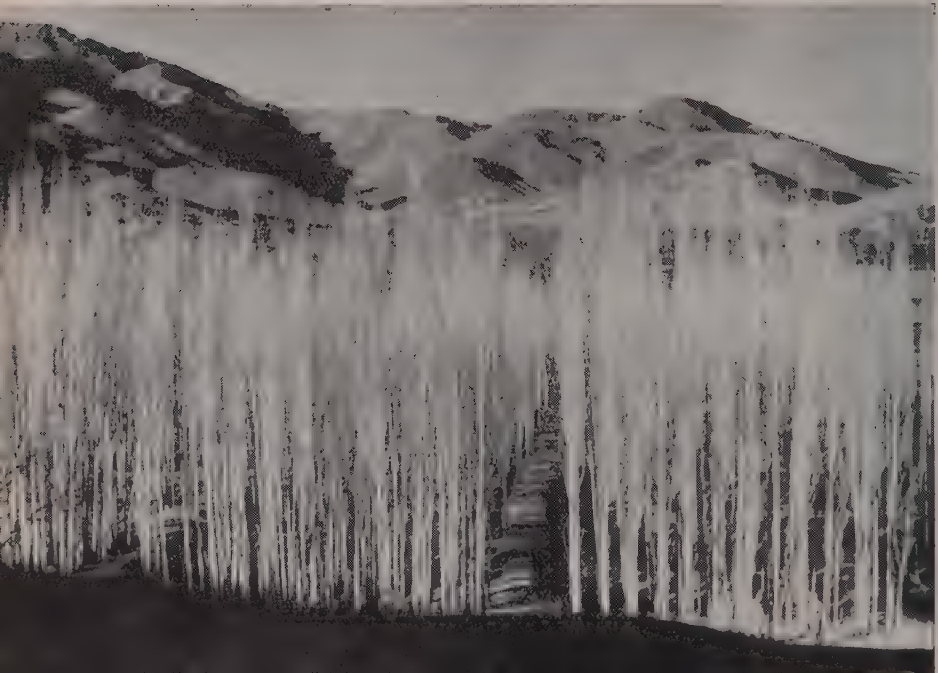


Figure 59. – Plantation of 5-year-old *P.* x *euramericana* cv. ' Blanquillo de Granada ' in the Valley of the Rio Genil, near Granada, Spain.

Courtesy *G. Giordano*

Figure 60. – An irrigated plantation of black poplars growing at an altitude of 2,000 meters at Paghman, Afghanistan.

Courtesy *A. Semple*



region where timber is not too scarce, while in Macedonia — which is poor in timber and situated more to the south — the narrow-crowned variety can be felled for use even when young.

Plantations with average or wide spacings are found in countries with a temperate climate where trees with wide crowns require a large growing space but where there is no demand for small-sized timber. The following examples will show that only this type of plantation can yield different classes of timber of market value. The examples will also show the probable trend of poplar stands in countries whose economy will change and veer toward the same requirements, and where poplars of improved strains will be planted.

From this broad review of the various spacings at present in use, the following general conclusions can be drawn:

1. In intensive cultivation, the poplar cannot be treated as a forest species. In all countries where only large-sized timber is of economic value the plants must be planted initially at their final spacing. In countries where the economy can still absorb some small-sized timber, a higher planting density can be adopted and intermediate thinnings carried out when the growth rate of the poplars decreases.

2. The question of spacing is linked with the following factors: climate (mainly light and temperature), the fertility and freshness of the soil, the types of poplar used, the method of cultivation and maintenance, the disease circumstances, as well as technological and market requirements.

Generally speaking, the following may be taken as the varying degrees of density:

a) very dense: the plantations with a space per tree of less than 10 square meters;
b) dense: the plantations with a space per tree of less than 25 square meters;
c) fairly dense: plantations with a space per tree of between 25 and 35 square meters;
d) normal density: plantations with a space per tree of between 35 and 45 square meters;
e) widely spaced: plantations with a space per tree of between 45 and 60 square meters;
f) very widely spaced: plantations with a space per tree greater than 60 square meters.

In hotter climates and in good soils, the lower range of spacing is adequate.

3. The closing of the canopy does not constitute the limit of the density, since root competition starts much earlier and its consequences are felt before those due to crown competition.

With these principles in mind, poplars can be planted in quincunx, squares or rectangles. Of these, arrangement in quincunx gives the tree the best growing conditions. It ensures that the best use is made of the atmosphere and, by giving freer entry to sunlight, the formation of asymmetrical trunks. This is only partially effective, however, since the east-west trunk diameter is always greater than the north-south trunk diameter, even when trees are equidistant from each other in all directions.

In western Europe only, where, as mentioned above, plantations at normal density or wide spacing are used, the layouts given below are recommended for the optimum utilization of the site and for the production of good quality timber.

a) planting in squares or in rectangles:

6 × 6 m., or 36 m^2 per tree and 277 trees per ha.
6 × 7 m., ” 42 m^2 ” ” ” 238 ” ” ”
6 × 8 m., ” 48 m^2 ” ” ” 208 ” ” ”
7 × 7 m., ” 49 m^2 ” ” ” 204 ” ” ”
7 × 8 m., ” 56 m^2 ” ” ” 178 ” ” ”
7 × 9 m., ” 63 m^2 ” ” ” 158 ” ” ”
8 × 8 m., ” 64 m^2 ” ” ” 156 ” ” ”

b) or better, planting in quincunx or equilateral triangles, which is more economic, as has been said above:

Length of sides of triangle m.	Distance between lines m.	Area per tree m^2	No. of trees per ha.
6.50	5.629	36.63	273
7.00	6.082	42.55	235
7.50	6.495	48.78	205
8.00	6.628	55.55	180
8.50	7.361	62.50	160
9.00	7.799	69.93	143

MIXED CULTIVATION

Although poplar is very often planted alone, in many Mediterranean countries and in the Near East its combination with farm crops is the principal characteristic of intensive poplar cultivation. Sometimes, too. it is planted in mixture with other forest species.

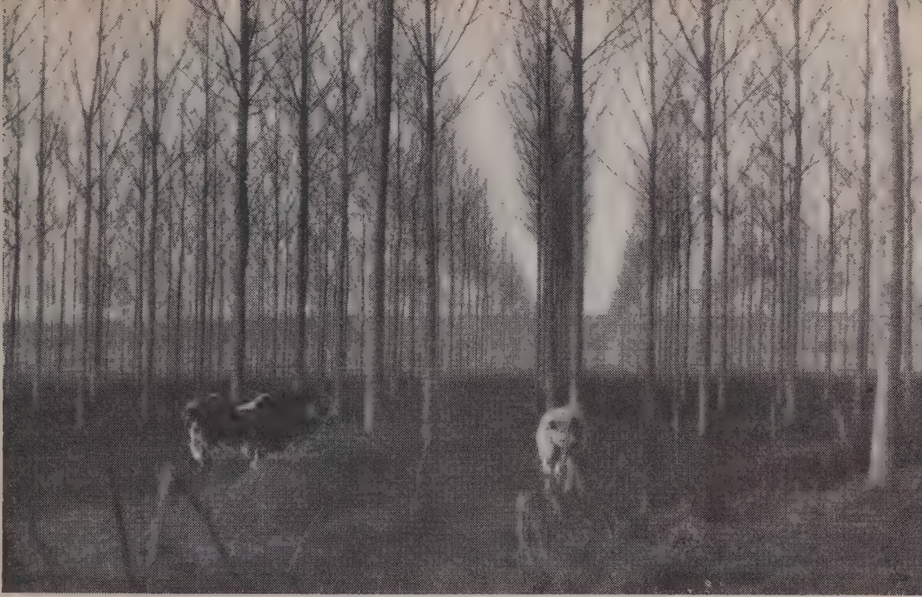


Figure 61. – Plantation of *P.* 'robusta' under pasture in the Dive Valley, France.

Courtesy *J. M. Venet*

Planting in mixture with forest species

Alder. Planting in mixture with alder (*Alnus glutinosa* or *incana*) is one of the most usual combinations. Alder are introduced between the rows of poplar at the rate of 1,000 plants to the hectare. The beneficial effect of alder on the growth of poplars is generally recognized, since its root nodules increase the nitrogen content of the soil. It also maintains the physical quality of the soil by producing humus, the main factor for keeping the soil in good structure and biologically active. The planting of alder is an indirect means of combating the large poplar longhorn beetle, as the base of the poplar stem is shaded from its fifth year, thereby creating conditions which are unfavorable to the swarming and mating of this insect.[5] Without claiming that results are always equally satisfactory, the following example may be quoted. A plot of former grassland in Belgium was planted in 1929 with *P.* x *euramericana* cv. 'regenerata' at a spacing of 8×10 meters. Half of the plot was maintained as grassland and continued to be grazed; the other half was underplanted with white alder. The soil type and quality were the same in the two plots and the poplars received the same treatment. The grazed half

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[5] On the other hand, it encourages attack by *Cryptorrhynchus lapathi* L.

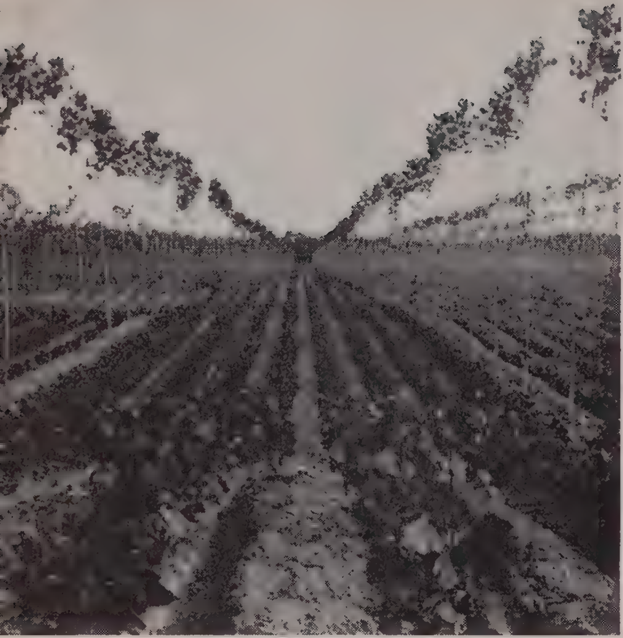


FIGURE 62. – 1-year-old plantation interplanted with nursery plants in the month of June.

Courtesy *Istituto Casale Monferrato*

FIGURE 63. – 11-year-old planting of *P. tremula* (from seeds originating in Poland) with a spruce understory, at Best, Netherlands.

Courtesy *R. G. Fontaine*

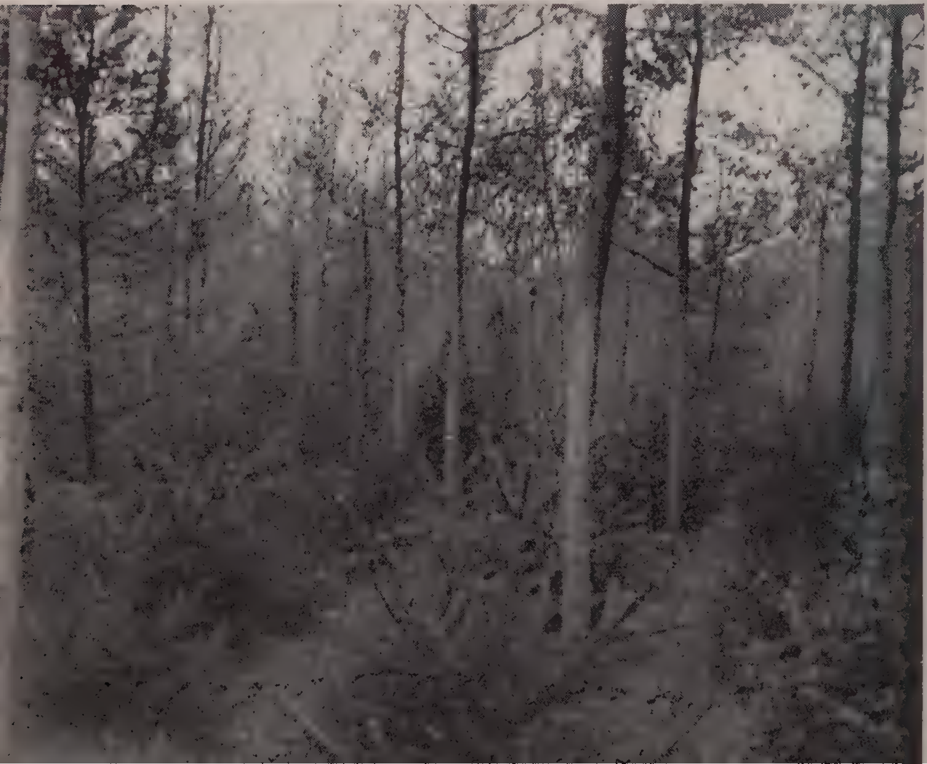
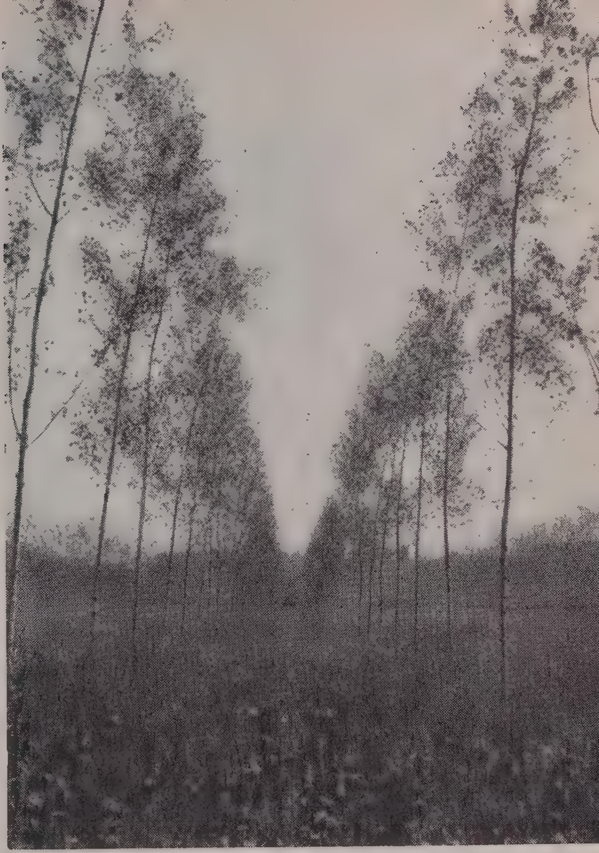


FIGURE 64. – A young plantation combined with wheat.

Courtesy
Istituto Casale Monferrato



had the benefit of animal manuring. Nevertheless, the following results were noted:

a) *Area maintained as pasture.* 31 trees with a total height of 19.50 meters (utilizable height 15 meters) and an average circumference of 1.36 meters at 1.50 meters from the ground. Average timber volume per tree, 1.36 cubic meters; volume per hectare, 176 cubic meters.

b) *Area with understory of alder.* 35 trees of the same height but with an average circumference of 1.68 meters. Average timber volume per tree, 2.170 cubic meters; volume per hectare, 272 cubic meters.

Spruce. Some countries plant poplar with an understory of spruce which are sold as Christmas trees. With the application of fertilizers such practice can be beneficial and without interfering with the growth of the poplars, provided there is an adequate water supply. The establishment of a permanent understory of spruce is, however, open to criticism, as it often takes up too much moisture from the soil.

Forest nurseries. In the early years of the stand the spaces between the rows can be used as beds for growing young poplars or other nursery plants.

Planting in combination with agricultural or horticultural forage crops

In western Europe some degree of grazing is very frequently practiced in poplar plantations when the trees have grown sufficiently so as not to be damaged by cattle. In the early years the grass is mown.

On the other hand, in Mediterranean countries, genuine agricultural or horticultural crops are combined with poplar growing. Manuring and other agricultural practices required by the agricultural crops favor the establishment and growth of the poplars, which in their turn provide a degree of protection. The financial outlay incurred in working the soil in order to establish the poplar stand is at least partly offset by the annual revenue from the agricultural produce.

In north Italy, where such practices are inseparable from intensive poplar cultivation, agriculture is carried out for the first eight or ten years in widely spaced plantations. A rotation is normally adopted for the first three or four years, preference being given to cleaning crops (maize, beet, potatoes) or to any other crop for which the soil requires deep ploughing and thorough manuring. These are followed by cereals such as wheat, rye or oats from the third to the fifth year and, lastly, by a forage crop such as clover. Lucerne should not be used. Care should be taken to break the root mat of the interplanted crops frequently in order to prevent asphyxia of the poplars' own root system. When market and labor conditions are favorable, vegetables can be combined very successfully with poplars.

Deep working of the soil in preparation for cleaning crops is of primary importance, for it encourages the poplar roots to penetrate more deeply, whereas they normally tend to spread near the surface. Hence, by drawing soil nutrients from a greater depth, fuller use is made of the soil.

A surface dressing of organic manure or chemical fertilizer is applied at the time of planting the mixed crops at the rate of 30 to 50 tons per hectare. The type of fertilizer used depends on the soil composition and the requirements of the crop.

The following formula is frequently used in the River Po Valley (quantities given per hectare):

Mineral superphosphate	800 to 1,000 kg.
Ammonium sulphate	250 to 400 "
Potassium salt	250 to 400 "

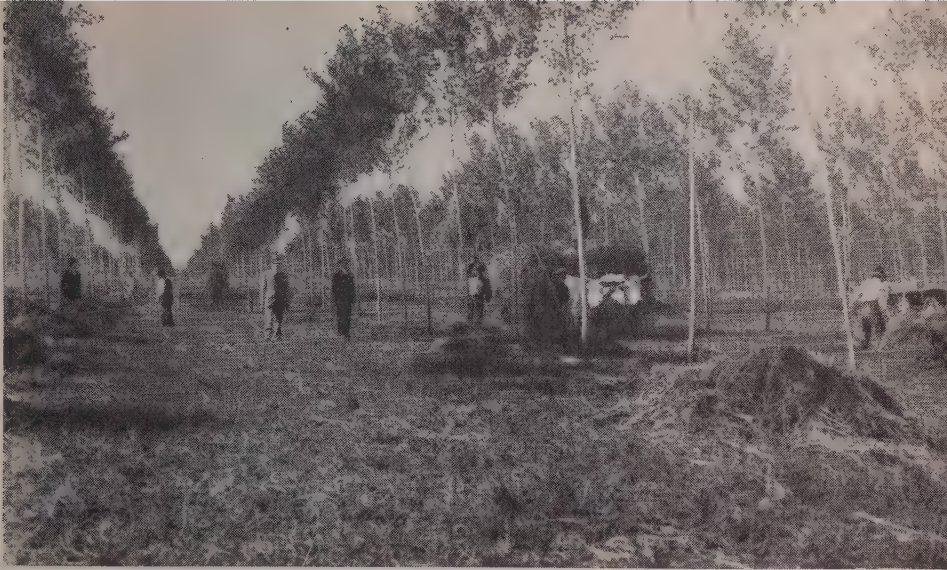


FIGURE 65. – A young plantation combined with forage crops.

Courtesy *Istituto Casale Monferrato*

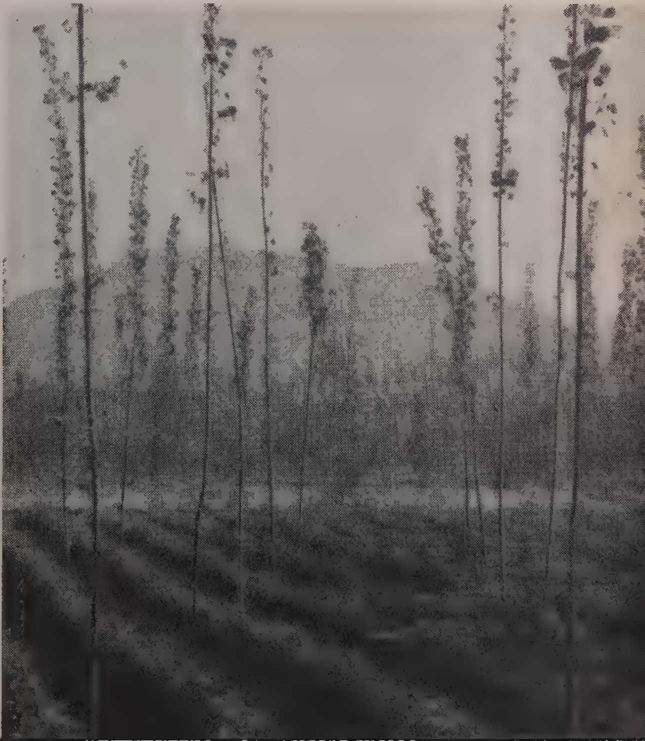


FIGURE 66. – 1-year-old plantation (established with 2-year-old sets) combined with a bean crop in the Valley of the Rio Genil, near Granada, Spain.

Courtesy *G. Giordano*

In cold and acid soils basic slag is a good substitute for superphosphate, and in certain cases thorough liming can be beneficial.

The practice of intercropping with the systematic application of fertilizers to the soil is definitely beneficial to poplar growth. A second-generation poplar stand established without previous manuring on very light infertile soil in the upper Po Valley yielded at 16 years of age trees with an average weight of 4 ½ cwt. (450 kilos). Trees on the same site are now intercropped after previous manuring, and at 13 years have an average weight of more than 12 cwt. (1,200 kilos).

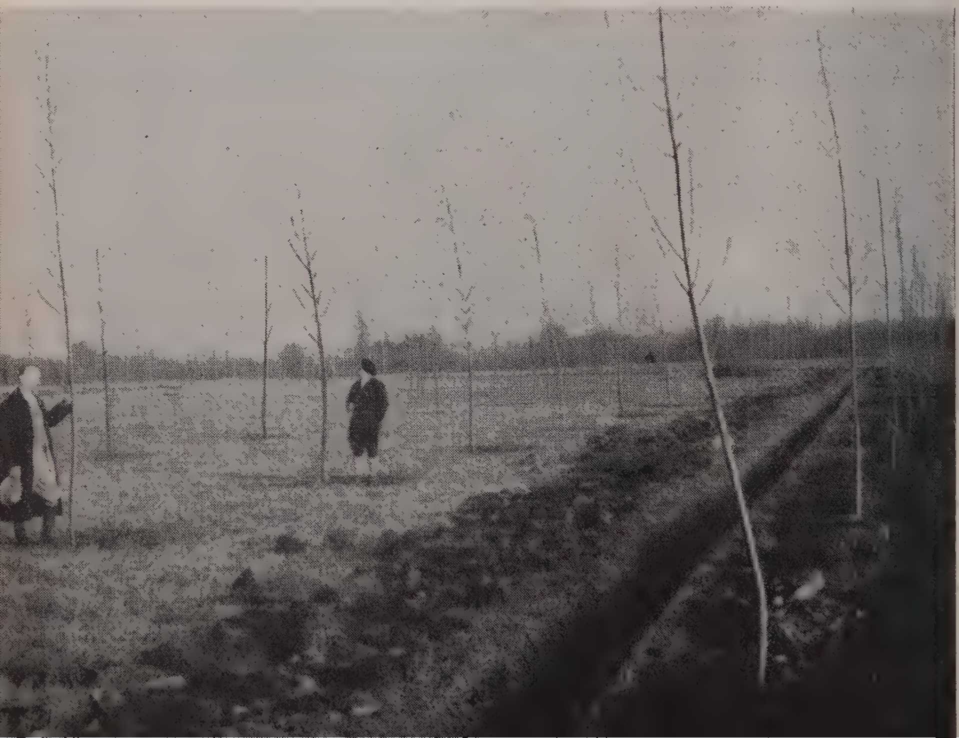
In the Near East, chiefly in Syria, poplar growing is generally combined with irrigated fruit and tree crops. Sometimes, when establishing the poplars, young apricot trees are planted between the rows to grow on after the poplars have been felled.

SOIL PREPARATION

Ploughing is always beneficial. However, since most of the sites used for poplars do not necessarily require such preparation, cultivation is usually only carried out when the cultivation of poplar is combined

FIGURE 67. – A plantation on drained marshland in Alsace, France.

Courtesy *J. Pourtet*



with that of an agricultural or forage crop. More often than not, the only ground preparation consists of digging the planting pits.

Two principal ground conditions can be distinguished:

1. *Ground which is moist throughout the year*

Here the water table is always high during the growing season and temporary flooding may occur at any time. It is, therefore, impossible to grow agricultural crops but poplars combined with woody plants or with pasture are fairly profitable. Preparation consists of clearing the ground of adventitious lush weed growth, which may compete intensely with the poplar for water. Preventive measures against weeds will probably have a more favorable effect than manuring. In addition, drainage of the soil and irrigation, if necessary, should be taken into account.

After these preliminary preparations, the essential operation is that of digging the planting pits and possibly the erection of a mound around the base of the young plant.

2. *Ground which is sufficiently sound and where the water table falls to an appreciable depth during the growing season*

The preparation of the soil combined with crop planting, as discussed above, in this case needs to be much more thorough and will consist of the following operations:

a) *Clearing and levelling the ground*

Complete removal of all natural vegetation is necessary to the point of uprooting stumps and clearing all traces of growth. If necessary, holes and the largest depressions in the ground must be filled in. If it is intended to carry out systematic irrigation, this levelling operation should be done very carefully.

b) *Initial deep ploughing*

The ground should be ploughed after each felling operation so as to remove the remains of all roots and stumps left by the previous crop, and to give the soil the necessary physical and chemical preparation. This should be done at the end of the winter or in early spring.

c) *Successive soil turning*

If a fairly long period elapses between the time of deep ploughing and planting, the initial cultivation must be followed by one or more light ploughings to facilitate the destruction of harmful spontaneous growth. Later, maintenance of the clearing crops will have the same result. The produce from these crops will offset the expense incurred in preparing the soil.

In both the ground conditions described above, digging the pits must be given careful attention, although this operation is made much easier by previous ploughing.

PREPARATION OF PLANTING PITS

The size of the planting pits must be such as to limit the volume of loose soil to which the roots have access, to ensure contact of the roots with fresh layers of soil and to see that the plants, which should be strong, are windfirm. The poplar needs a friable soil layer of 0.5 to 1 meter. The depth of the pit should be at least 70 to 80 centimeters in deep, loose soil and its surface width should never be less than 40 to 50 centimeters. If necessary, the pit can be as deep as 1 meter or more in order to reach the fresh soil layer. On the other hand, in moist soil a smaller pit — 40 or 50 centimeters in all directions — will be adequate, and sometimes it may even be possible to plant at the surface after the soil has been worked. In compact soil the depth need not exceed 60 centimeters but the surface width will need to be as great as possible. A method sometimes used is to connect all the holes in the same row by a deep trench previously marked out by the plough.

If the water table is too low, a pit of normal depth (about 1 meter) is dug and the bottom pierced in the center with a stake or special earth auger; this is the practice in the dunes of the Venezia region of Italy where the total depth is often 2½ to 3 meters or more. It has the advantage of ensuring that the young plant is firmly planted and that the root system, by developing in layers, can draw on water and other nutrients from a considerable depth. In this case sets are sometimes used.

It is important to bear in mind that, since young plants should be used, the pit must be of sufficient depth to ensure that the young tree is completely windfirm without having to be staked.

Planting pits can also be made by using explosives or with the aid of machinery.

Use of explosives. Tests were made with explosives for pit digging in Belgium in 1952 and all the young plants took root. A hole 60 to 80 centimeters deep, according to the type of ground, is drilled, using a crowbar. A cartridge charge of 100 grams of high explosive with a base of ammonium nitrate is lowered into each hole, which is then filled with earth and, if necessary, with fertilizer if it is intended to manure the ground at the same time. The soil should be lightly packed. A charge of 100 grams has the effect of a low-pressure blast; it does not produce a crater but loosens about 3/4 to 1 cubic meter of ground and cracks 2 to 3 cubic meters. It is advisable to wait until a slight settling of the soil occurs before proceeding to plant. In the soil thus settled, it is easy to dig the pits with a spade.

Planting costs are not necessarily reduced by using explosives (compared with the digging of pits and insertion of the plants), or at least not appreciably; but without increase in cost the explosive has the advantage of loosening or cracking a volume of ground five or six times greater than is normal, and of overcoming a possible labor shortage.

Use of machinery. Various machines designed for other purposes can easily be converted into mechanical diggers by means of a simple attachment. A soil auger attached to the frame of a motor cultivator becomes a mechanical auger. Similarly, the motor of portable saws used for the felling and crosscutting of trees can be made to drive an easily adaptable auger.

There are also special augers which can be fitted to a tractor equipped with a hydraulic lift device. Those at present in use have diameters ranging from 42 to 70 centimeters and are capable of boring holes to a depth of 90 centimeters. The driver of the tractor also operates the auger, while another man controls the drilling at the points fixed previously when marking out the rows. Thus on easy ground, as in Italy for example, 600 to 800 holes can be drilled in a day, or the equivalent of a day's work by a group of 12 to 14 workmen. In this way not only is the work speeded up — a very important factor in making the most of the planting season — but it is carried out more efficiently and at much lower cost.

PLANTING

Season. As the soil and climatic conditions vary within the same region, it is advisable to make all possible use of local experience to determine the best planting season.

In countries with well-defined seasons, the times to plant are autumn, winter and early spring. The best month for autumn planting is November, since the plants are without leaves and the roots can still grow a little during the autumn and winter. The soil consolidates gradually around the root system, which takes a firm hold and is thus ready to act with the first resumption of growth in a good fresh soil the better aerated by winter frosts. The plants get off to a good start in the spring.

Autumn planting should, however, be avoided in cases where the soil is waterlogged in winter, as the roots can become asphyxiated and even die if exposure and strong winds are prevalent. For reasons of manpower, administration and plant supply, the most common time for planting is, in practice, the winter (except during extremely cold weather or in periods of frost) or the spring. In the latter case, care should be taken that the plant is rooted, preferably very early in the spring, or at any rate before the first signs of leafing, which occurs at different times according to the type of poplar.

Planting methods. Efficient working methods are necessary if the roots are to be prevented from drying off during transport or in the course of the various preliminary operations. It is useful to soak them first in a solution of clay, cow dung and water.

The principal element of success in planting is the time factor. The least possible time should elapse between the young plant leaving the nursery or trench and its insertion, since in the intervening period its condition is highly precarious. Planting should, therefore, be avoided, if possible, when the sun is hot, when there is a high wind or in very cold weather. During transport, whether by lorry or train, care should be taken to cover the plants.

Black poplar hybrids which are commonly used in intensive cultivation all have the ability to throw out vigorous roots from the stem. For this reason, when planting them there is no need, as is usually the case with other trees, to see that the root collar of the young plant is flush with the ground. On the contrary, the collar should be sunk to a lower level than in the nursery, at least 20 to 50 centimeters, or even more if it is necessary for the roots to touch the bottom of the pit, whatever its depth, in order that they can reach the permanently moist soil.

There are several reasons for using this method. Since tall strong plants are generally used, they need to be planted very firmly to prevent them from swaying, either due to the wind or other causes. Such movement makes the plants more vulnerable to damage by frost and drought or promotes tearing of the beneficial rootlets, especially when the plant has not been long in position. Firm rooting without the necessity of staking is important, as the operation of staking is often harmful and is always costly and intricate. In some countries, when planting, two thin strips of bark are cut at the sides on the part of the plant which will be placed underground. This is done to stimulate the growth of adventitious roots, that is, roots which sprout from the surface of the cut and which are stronger than those which sprout from the bark.

Mounding, which is harmful in dry ground because it stimulates the sprouting of superficial roots which are likely to die off at the first signs of drought, is advisable on the other hand in damp ground, or where the water table is very high. It facilitates rooting, increases wind firmness and helps to prevent asphyxia of the roots. Plants can be planted in fairly large mounds prepared beforehand. Where mounding is necessary, so, frequently is drainage, so that the soil from the drains can be used for mounding. Another procedure is the following: the plant is only inserted to a depth at which its roots are in contact with good soil. The earth is then heaped to form a mound 50 centimeters high and 1½ meters or more in diameter round the plant.

When digging the planting pits it is advisable to separate carefully the turves, the topsoil, subsoil and even the soil brought to the site. A mineral fertilizer can be mixed with the soil. If the pit is to receive a fertilizer, this is placed at the bottom and then covered with topsoil to form a small mound on which the roots are spread in their natural position.

Planting is usually performed by two men: one holds the plants upright and in line with the others, taking care that they are all at approximately the same height, while the other fills in the pit. Filling in is done with the best soil, which is at first thrown in lightly in small quantities, compacting it down by tapping gently with the spade. The plant is, at the same time, pulled gently by the first planter to help the soil to penetrate between the roots. The soil is then lightly packed, using the spade handle, after which filling in is continued with the best soil, first heeling it from time to time, while taking care not to damage or break the roots. (When the pit is two thirds full, it is helpful in dry soils and climates to pour in a pail of water; in this case the remaining third is filled in the following day.) Allowing for natural settlement, the pit should be filled to slightly above ground level.

FERTILIZERS

The special case of manuring when poplar cultivation is combined with the growing of farm or grass crops has been discussed earlier in connection with mixed cultivation. Here it is intended to discuss the subject more generally.

Manuring can be carried out at the same time as planting, the fertilizer being mixed either with the soil used for filling in the planting pits or applied as a surface dressing. It can also be applied to the young trees during their early years. This is a question which still requires study but experience in different countries has already shown that the use of fertilizers during these early years pays dividends.

In efficient cultivation, selected plants with a rapid growth rate are used; they are consequently heavy feeders and require for their development rich, suitably manured soil. A plant with a good growth rate when young always remains more vigorous and reaches felling size several years earlier, which entails an increased rate of investment.

Quantities. Depending on the fertility of the soil, the amount of fertilizer will vary between 500 and 1,500 grams per tree, applied either in a single dressing at the time of planting, or after planting, or in three successive dressings at the rate of 500 grams annually.

Types of fertilizers and their application. The kind of fertilizer to use depends on the composition of the soil, which is determined by chemical analysis. The analysis of poplar wood ash, given in another chapter, shows a high proportion of potash, phosphoric acid and lime. Its requirements of potash are exceeded only by those of elm but it easily takes first place for phosphoric acid.

Nitrogen often exists in sufficient quantity in soils intended for poplar cultivation. However, an application of 100 grams of nitrate of soda or lime to each tree in the first or second year gives an early start to spring growth; it is also an indirect means of combating *Dothichiza populea*.

Preference is usually given to potassic or phosphate fertilizers. Basic slag in the proportion of 80 to 70 percent of 20 to 30 percent potassium sulphate (sulphate is preferable to chloride) is a good formula.

Direct contact between mineral fertilizers and the roots is to be avoided. If they are mixed with the soil used for filling in the pits, they should not be combined with the soil which comes into direct contact with the roots. The most common practice is to dress the freshly turned soil around the stem, where the roots are concentrated, after the pits have been filled in. For successive dressings in the second or third year, care must be taken to cultivate the soil beforehand, having first cleared the ground over a sufficient radius.

If liming is necessary, this is generally done before planting, although it can also be done at the actual time of planting or later. If it is done at the same time as planting, the lime is mixed with the soil used for filling the pits but not included in the layer which comes into immediate contact with the roots.

If the soil is sufficiently rich in phosphorus or potash, organic manure can be applied in the proportion of 1 kilogram of well-rotted manure to each tree the first year, and 2 kilograms per tree for the next two years. The manure is laid on the surface around the foot of the tree on the cultivated soil, and is then covered with a little earth or by replacing the turf. It can also be put in the pit at the time of planting.

The addition of compost, alone or enriched with a nitrogenous fertilizer, in the planting pit, will stimulate the growth of root hairs.

REPLACEMENTS

Even if all precautions are taken when planting, replacements are often necessary. There should be no hesitation in replacing plants which, from the very first, show signs of low vitality even though they may sprout shoots at the base. The additional expense is always largely compensated if the replacements are made in time and with vigorous plants. Plants for this purpose should be better developed than those used in the initial planting, so that they soon catch up with those already established. Nurseries should always hold in reserve a certain number of plants of particularly good diameter and height.

The best procedure is to make replacements in the second year after planting. This is already very risky when the young trees have reached their third year and is not recommended after the fourth year. Such plants now have to compete with vigorous well-established trees. As newcomers they may lag behind throughout the whole of the rotation and ultimately yield timber which is inferior in quantity and quality, while at the same time prejudice to some extent the growth of the other trees in the stand. In this case the additional expenditure involved can be taken as a total loss.

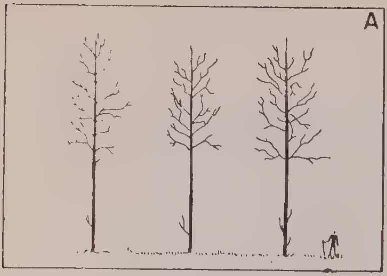
Planting of replacements is done along the same lines as for the initial planting and should be carried out with, if anything, more care in order to ensure good establishment and rapid growth. It is generally advisable to plant replacements in the autumn, in order to improve their chances of establishment and thereby gain, virtually, a whole growing season.

EARLY PRUNING, TRIMMING AND PRUNING

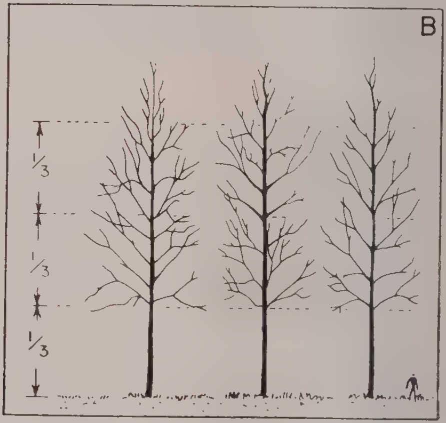
The poplar is subject to a number of operations at the time of planting or during its growing period. These are principally the following: *early pruning*, at the time of planting or for a few years after planting, to ensure a proper balance between the roots and crown; *trimming*, which consists of cutting off the epicormic shoots which appear after the occa-

FIGURES 68 to 71. – The proportions of stem to crown in the different stages of pruning.

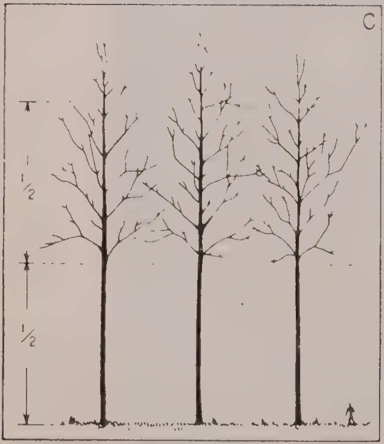
Courtesy *Istituto Casale Monferrato*



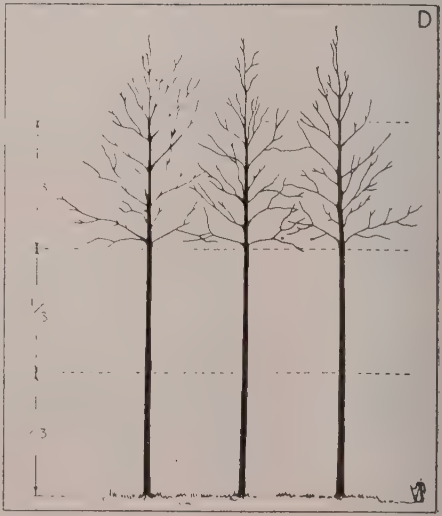
First stage



Second stage



Third stage



Fourth stage

sional or systematic removal of branches; and *pruning*, the aim of which is to increase the marketable length of the bole and to improve the produce by systematically removing the side branches.

Nature and time of different operations

Early pruning. In countries of western Europe where the soil and climate give no cause to suspect a state of unbalance between transpiration and the moisture absorption of the young roots, as yet not firmly established and still small, poplars are planted with all, or at least some of their side branches. Sometimes, particularly in Italy, evaporation is reduced by removing all the branches with secateurs, leaving only the characteristic small stump where the branch enters the stem, so as to reduce the wound or surface of the cut, and hence the chance of parasitic fungi entering, particularly *Dothichiza*.

After the plant is inserted and during its early years, it is necessary to preserve at all costs all the original branches, or those which have grown again after transplanting. The best type of plant is, in fact, one which is sturdy and well balanced and which has the maximum of leafy shoots — its respiratory and absorptive organs. It is thus best equipped for vigorous growth and resistance to attack from insects and diseases. Early pruning, on the other hand, causes wounds through which parasites, including *Dothichiza*, can gain entry. It should, therefore, be avoided up to the fourth or fifth year after planting, except in the following cases:

a) to remove double leaders; and
b) to shorten a side branch which throws the crown out of balance.

Trimming. Epicormic shoots appear on the trunks of trees, mainly at points where branches have been removed. They are due to the activity of dormant buds and are stimulated by excessive pruning, although their incidence depends also on the variety.

Epicormic shoots must be removed at the latest two years after they make their appearance, and it is advisable to start removing them in the first year, as the operation is then easier. It is often necessary to repeat the operation for two or three successive years. In the countries of western Europe the best time for this is between July and August. However, if it is intended to use epicormics for cuttings, they must be well developed and they should be cut off preferably in the spring, the best time for the insertion of cuttings.

Summer pruning discourages the growth of epicormic shoots, and it is therefore sometimes carried out at the same time as trimming, at the end of August, or, in the more southerly countries, at the end of September. In this way the small wounds still have time to heal before the winter and fewer epicormics appear.

Pruning. While this operation can increase the value of the timber yield, it can at the same time cause the most serious depreciation. As has been said earlier, pruning should not be practiced before the third or fifth year after planting. Furthermore, the knots produced up to this age remain in the central section of the bole, which is often not used.

Pruning should be moderate; it must be concerned with the equilibrium between the crown and the roots in order to ensure a proper feeding of the tree. Excessive pruning stimulates the growth of epicormics and hinders healing of the wounds. Poplars grown in stands are not pruned naturally as in the forest, and the presence of dead knots in the wood naturally causes depreciation.

Pruning should be done progressively and in such a way as to leave ultimately a crown equal to one third of the height of the tree. It can be divided into four phases, differentiating between stands felled at more than 20 years and less than 20 years of age.

Poplar stands felled at more than 20 years

First stage (up to 5 years): no complete pruning is carried out, only early pruning and trimming.

Second stage (5 to 10 years): trimming is continued, and pruning of the lower third of the stem carried out.

Third stage (10 to 15 years): pruning is extended to the lower half of the stem and, if necessary, trimming is continued.

Fourth stage (15 years to the time of felling): during the early years of this period pruning is extended to the lower two thirds of the stem. The crown keeps this proportion up to the time of felling.

Poplar stands felled at less than 20 years

A poplar stand in Italy felled at 18 years is taken as an example.

First stage (1 to 3 years): no pruning.

Second stage (4 to 5 years): pruning on the lower third of the stem.

Third stage (6 to 8 years): pruning on the lower half of the stem.

Fourth stage (8 to 10 years, or the first two years of the last period): up to two thirds of the stem.

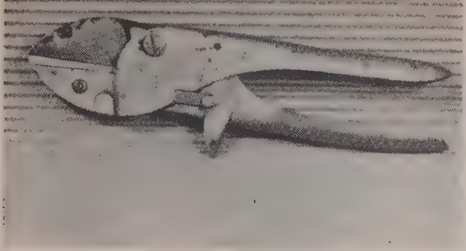


FIGURE 72. – Secateur.

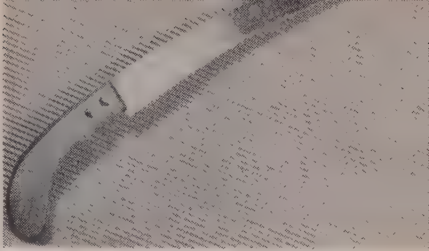
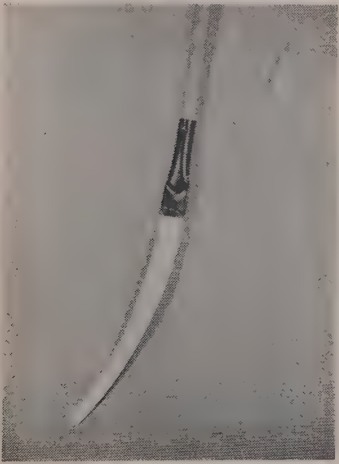


FIGURE 73. – Hand saw.

FIGURES 74 to 75. – Saws for mounting on 2-to-4-meter poles; the model on the right is used for thicker branches.



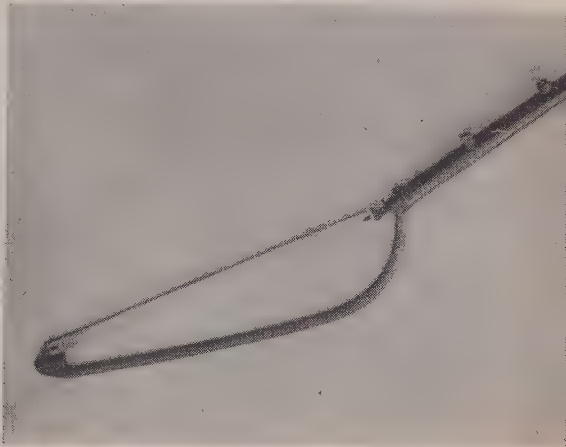


FIGURE 76. – Pruner mounted on a 2-to-4-meter pole for removing double leaders and epicormic shoots.

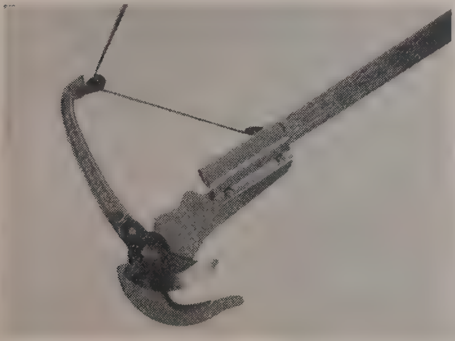
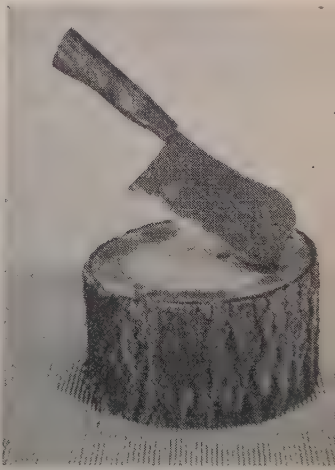


FIGURE 77 – Billhook.



FIGURES 72 to 77. – Tools used for early pruning, trimming and high pruning.

Photos courtesy *G. Houtzagers*

By pruning the tree in these proportions the essential balance between roots and crown is assured.

Pruning practices which virtually strip the stem, leaving the crown reduced to a single tuft, should be avoided at all costs.

Pruning is a necessary evil, but its disadvantages can be considerably mitigated if it is systematically carried out:

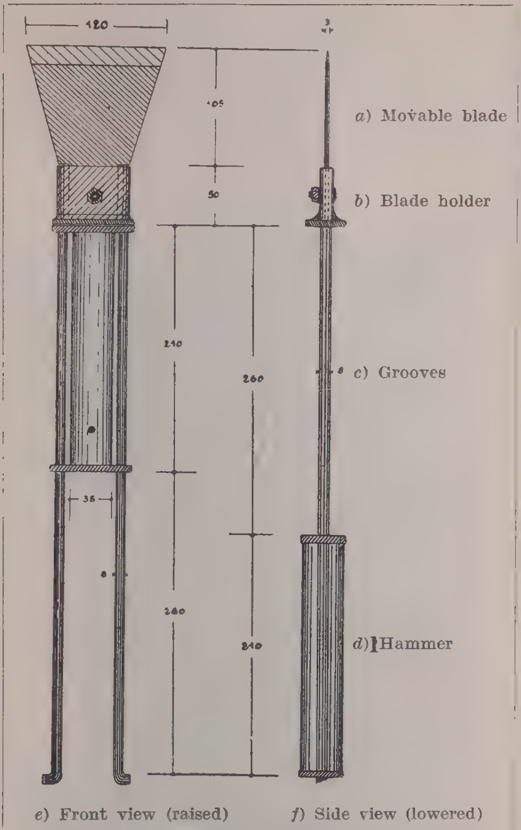
- *a*) by restricting the removal of live branches to those not exceeding 6 or 7 centimeters in diameter; and
- *b*) by carrying it out at the most suitable time. Here it is necessary to differentiate between the pruning of dead and live branches:
  - *i*) *Dead branches.* In theory all seasons of the year are suitable, except during frost. It is, however, preferable to avoid the summer, since the base of the branch may still retain some vitality and by severing it live parts of the tree may become exposed. In practice, removal of dead branches is performed at the same time as the removal of live branches.
  - *ii*) *Live branches.* Although the poplar is less affected than other species by the removal of live branches, on account of its vigor and rapid growth, there is less freedom of action than with dead branches, since the sap moistens the wound.

In theory, the best season for pruning is at the end of the winter (February to the beginning of March). The wound thus starts to heal at the beginning of the growing season and continues to heal throughout the season, so escaping the harmful effects of heavy frost. It is possible to prune in winter provided there is no fear of severe frost. In countries with a temperate climate the end of August and the beginning of September are equally suitable if it is desired to combine pruning and trimming.

The rule can be more simply formulated by stating when pruning should be avoided:

During the summer. Decay sets in more easily, as there is an abundance of sap, this preventing any antiseptic or protective dressing from sticking and so reducing their effect. It is advisable to apply a protective dressing after each operation.

During the autumn. The tissues which are still growing over the wound are too delicate to withstand the rigors of winter.


120
3
105
50
a) Movable blade
b) Blade holder
240
260
8
c) Grooves
35
8
280
240
d) Hammer
e) Front view (raised)
f) Side view (lowered)

The hammer chisel (1,600-gram model): the 750 gram model is similar, with the hammer also running along grooves.

FIGURE 78. – Hammer chisel.

Courtesy *Dubois*

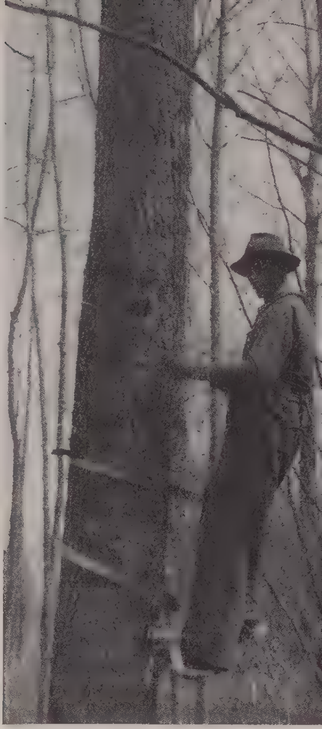


FIGURE 79. – The "tree bicycle" climbing device in operation.

Courtesy *J. Pourtet*

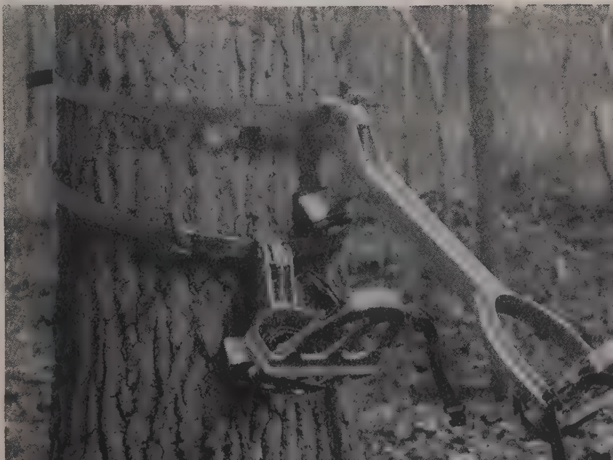


FIGURE 80. – The "tree bycicle" ready for use.

Courtesy *J. Pourtet*

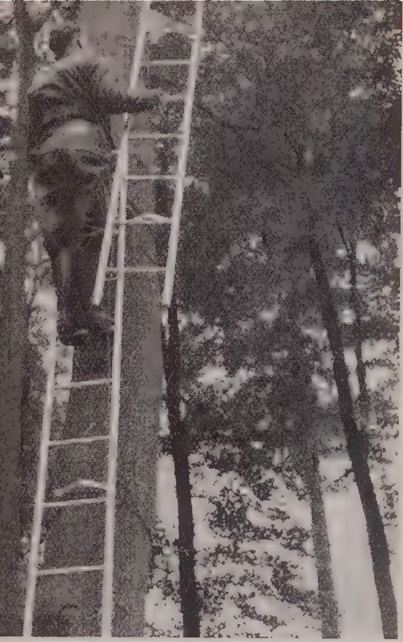


Figure 81. – The operator climbing with a section of the ladder.

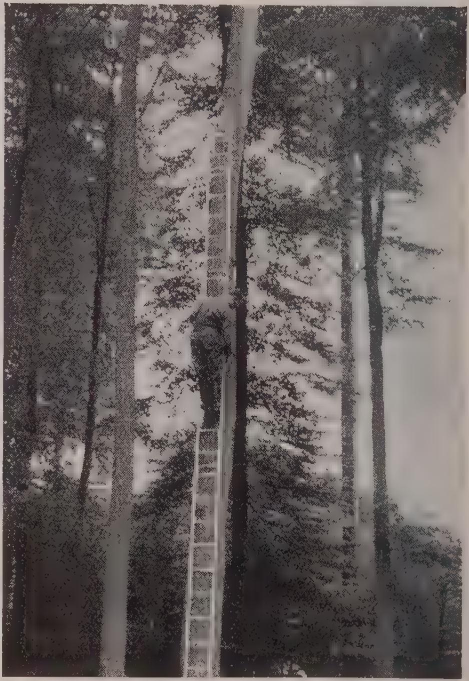


Figure 82. – Attaching a section of the ladder.

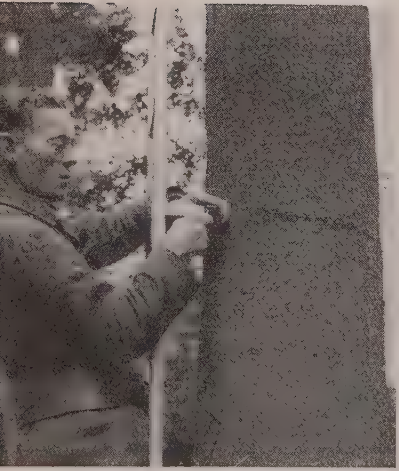


Figure 83. – Locking the chain in position.

Figures 81 to 84. – Demonstration of climbing. The "tree ladder."

Photos courtesy *Reginster*

c) by leaving intact the protective swelling which has started to form at the base and around the dry branch, and which will finally seal itself if the branch has not been dead for too long;

d) by using very sharp tools which will leave a clean surface cut;

e) by following up the removal of branches with the application of an antiseptic or protective dressing;

f) by not leaving a stump. On the principle that pruning a dead branch is less open to risk than removing a live one, some poplar growers initially lop off part of the live branch, to a certain distance from the trunk, and leave the stump to die off naturally before removing it. This practice is highly undesirable as it encourages the introduction of decay.

Pruning tools and climbing apparatus

The *tools* used for the efficient practice of the different types of pruning described above are, depending on the size of the branches — secateurs, billhook, saw, hatchet and chisel. They must be skillfully operated and should be kept very sharp so that the cut is clean, smooth and without a jagged edge.

Secateurs are used for cutting off thin shoots. Care should be taken when using them that the butt does not cause bruising, and the blade should therefore be turned toward the part of the shoot to be preserved. To avoid making large wounds, which encourage the entry of parasites, the cut should never be completely flush with the stem. When cutting, care should be taken not to bend the branch too much as it may easily break off owing to the fragility of the wood.

The *billhook* should be of a size to allow the operator to use it with sufficient force to make the cut easily. If the branches are not too big, it may be sufficient initially to give several sharp upward strokes followed by downward strokes, to avoid splitting the branch and injuring the stem.

When the branches are larger, a *pruning saw* is used. This gives a less satisfactory cut but the ease and speed of operation, even by relatively unskilled labor, more than offsets the rougher cut.

Secateurs, the billhook and saw, or a simple blade, are often attached to the end of light rods of varying length, made up of several component parts.

The *hatchet* can be employed when highly skilled labor is available. In expert hands it produces rapid and excellent results but in unskilled hands it can cause considerable damage.

Chisel. There are numerous types of chisels, for example the hammer-chisel. This tool consists of a cutting blade fitted at its base into a blade holder which acts as a striking block for the " hammer " or steel tube, having a striking block matching that of the blade holder; the implement is attached to the end of a handle which fits into the tube, or hammer, by means of a wooden socket. Two special steel grooves are fixed to the blade holder in the extension of the blade, so that the hammer is guided in exact alignment with the blade. The handle is composed of sections 2 meters in length, which fit one into another, the total length being from 6 to 8 meters, depending on the weight of the hammer. This chisel is particularly suitable for the early pruning of young poplars. It easily lops off branches up to 5 centimeters in diameter, whereas an ordinary chisel can only cut one-year-old shoots. In this way pruning can be done to a height of 10 meters up the stem without climbing the tree.

Climbing apparatus

The use of crampons should not be allowed, since irrespective of the type used, they all leave, to some degree, permanent traces in the wood. Therefore, to reach considerable heights, a light ladder (aluminium) composed of several sections can be used, or climbing apparatus, other than crampons, which grip the trunk.

When pruning is to be carried out on a large scale, it is advisable to employ skilled labor.

As a general rule, it is not advisable to have pruning done on a piece-work basis, for speedy work is not necessarily efficient work; nor should pruned branches be given to the workmen, in case they are tempted to over-prune in their own interests. It is preferable to pay them a good daily wage.

THINNING

Thinning is rarely economic in intensive poplar cultivation; it is, in fact, only considered in stands with an initial density of over 400 stems per hectare. If the trees have a larger growing space (about 50 square meters), they reach an exploitable age and size without requiring intermediate thinning. Thinnings are therefore only provided for or envisaged in the countries mentioned above, where small-sized timber meets local demands and where the stems removed find a ready market.

It should be noted first of all that with intensive poplar cultivation there is no question of *selection thinning*, which is reserved solely for natural stands, multiclonal plantations, and the forest cultivation of poplars.

Since the stands under consideration here are geometric plantations established from selected plants, and in principle belonging to a single clone, thinning is, consequently, a rigid procedure which consists in the systematic removal of a number of trees determined by their position in the stand. Its efficiency is uniform and will affect all the trees left standing. It can also result in excessive spacing.

There are two aspects to thinning: one physiological, the other economic. With the first, thinning should be undertaken when there are initially too many trees, and when the planter intends to remove in one or more thinnings some of the stems as an intermediate crop, in order to maintain the remainder to the predetermined felling age.

Thinning must be carried out at the right time, which is before the crowns meet. If it is left too late, the poplar no longer responds, or only very slightly. Its response to thinning, with only slight variations according to the type of poplar, decreases considerably with age. The planter is therefore obliged to carry out the operation at an age which is determined for him, whether or not the market conditions are favorable, at the right time and in good conditions; hence the economic aspect. If there is a slump at the time and thinning is postponed, the main crop will suffer; it will suffer even more if, from negligence or other causes which may be outside his control, he does not carry it out at all.

In practice, thinning is only performed in countries where the timber needs are such that even very small sizes of produce have a market value.

The aim of intensive poplar cultivation is to obtain the highest profit, and the poplar grower should not be diverted, therefore, from attaining this end by theoretical considerations. Also countries where a more complex economy requires larger size classes of timber, thinning operations are not economic. as can be seen from the following data, from experiments carried out on ground attached to the research station at Casale Monferrato, Italy. These trials were carried out on four types of poplar stands, all 11 years old:

1. In the first plot the trees were planted at a spacing of 3×3 meters and were maintained without thinning until felled at the age of 11 years, made necessary by the overcrowded condition of the stand.
2. In the second plot the trees were also planted at a spacing of 3 × 3 meters, but a thinning was carried out at the age of 6 years (one row in two was removed in both directions at right angles to each other. bringing the spacing to 6×6 meters).

TABLE 5. – DATA ON A PER HECTARE BASIS FOR A DENSE UNTHINNED STAND, A DENSE THINNED STAND, A MEDIUM-SPACED STAND OF UNSELECTED MIXED EURAMERICAN HYBRIDS (" CANADIAN POPLARS ") AND A MEDIUM-SPACED STAND PLANTED WITH A SELECTED CLONE[1]

Produce classes and increment	Stand 3 × 3 m. (clone 154) unthinned, felled at 11 years				Stand 3 × 3 m. (clone 154) thinned at 6 years, felled at 11 years				Stand 10 × 3.5 m. (mixed hybrids " Canadian poplars ") unthinned, felled at 11 years				Stand 10 × 3.5 m. (clone 214) unthinned, felled at 11 years			
	Volume		Value[2]		Volume		Value[2]		Volume		Value[2]		Volume		Value[2]	
	m³	%	lire	%	m³	%	lire	%	m³	%	lire	%	m³	%	lire	%
Timber for:																
Plywood	11.951	*5.9*	179 265	*10.3*	22.850	*10*	342 750	*15.8*	92.683	*34*	1 390 245	*46.4*	118.280	*34*	1 774 200	*46.4*
Sawing	47.971	*23.3*	479 710	*27.5*	60.932	*27*	600 932	*27.7*	103.680	*38*	1 036 800	*34.5*	132.320	*28*	1 323 200	*34.5*
Paper pulp	145.246	*70.8*	1 089 345	*62.2*	*e* 74.000 *f* 68.548	*63*	*e* 708 346 *f* 514 310	*56.5*	76.425	*28*	573 188	*19.1*	97.560	*38*	731 700	*19.1*
Total timber output	205.168	*100*	1 748 320	*100*	226.330	*100*	2 166 338	*100*	272,788	*100*	3 000 233	*100*	348.160	*100*	3 829 100	*100*
Indices	*1.00*		*1.00*		*1.10*		*1.23*		*1.33*		*1.71*		*1.70*		*2.19*	
Number of trees felled	1.110		—		*e* 834 *f* 276		—		285		—		285		—	
Average volume per tree in m³	0.1847		—		*e* 0.088 *f* 0.5511		—		0.9574		—		1.2219		—	
Average annual increment in m³	18.65		—		20.58		—		24.55		—		31.65		—	
Average annual increment in value per hectare (lire)	—		158 938		—		196 939		—		272 748		—		348 100	

---

[1] The value of thinnings was capitalized up to the end of the rotation at 5 percent.
e = thinning *f* = final felling

[2] Unit prices of timber loaded for transport from felling site:
for plywood: 15,000 lire per m³
for sawing: 10,000 lire per m³
for paper pulp: 7,000 lire per m³

3. In the third plot several types of unselected Euramerican poplars were planted at a spacing of 10×3.50 meters and were maintained without thinning until felling age.
4. In the fourth plot the same spacing was employed as in the third plot but with a selected type of Euramerican poplar (*P.* ' I-214 ').

The direct conclusions which can be drawn from this table are as follows:

a) the densest stand produced the highest yield in quantity, quality and revenue;
b) thinning carried out after six years had much less effect than a wider initial spacing;
c) the use of a selected type brought about an increase in quantity and in revenue.

These results would be still more valuable if complemented with figures for planting and maintenance costs, which would naturally be higher in the case of the denser plantations.

Each country will need to determine its own most favorable economic solution to the problem of thinning from experience rather than theory, by comparing the results of plantings made on criteria based on the needs of its own market.

B. Poplar growing in lines

The basis of this type of planting is the line or row, generally single or double.

In its intensive form this has long been the only type of cultivation practiced in the Netherlands and Belgium, and still easily predominates in both these countries, as well as in many regions of France, Italy, Switzerland, and above all in the Mediterranean region and in the Near East.

Line planting is allotted a separate section, not because the principles of cultivation applied to it differ greatly from those described for intensive cultivation, but to emphasize its great importance in timber production, in more intensive land utilization and its strong influence on the environment. This last aspect deserves particular stress here.

The poplar has a foremost place in the composition of the stately and orderly rows of trees which enclose the pastures and meadows of western

Europe, the farm crops, horticultural and forage crops of southern Europe, and which border roads and canals almost everywhere. This magnificent heritage is not merely an important source of material for the timber market; it is also a real factor in man's endeavor to make better use of the land, by improving the agrarian environment through the creation of the microclimate best suited to agriculture.

In the section of this chapter dealing with poplar growing in stands, the close association between this type of cultivation and agriculture proper has already been seen. If intensive poplar growing has as its principal aim the increased production of utilizable timber, this is not its only aim, and the beneficial effects of a well established and well distributed tree cover are incontestable. Trees reduce damage by wind both to the soil and to vegetation, protect herbaceous crops against excessive insolation, and by inducing photosynthesis through retaining in their vicinity an equitable amount of CO_2, regulate the balance of water in relation to precipitation, the water regime and evaporation. Comparison between agricultural production in regions having shelterbelts with regions where there is no such protection, has shown that fields bordered by trees are not less productive; on the contrary, when there is a proper balance between the two, trees have even helped to raise agricultural production.

The work of building up, or in some cases, rebuilding the natural equilibrium which man destroys by agricultural practices is under way in many countries. A typical example is the Po Valley, whose western provinces, with their dense network of rows of trees composed chiefly of poplar, are in the most advanced stage of land development. Mention should also be made of the famous *ghouta* of Damascus where the association of agriculture with shelterbelts of poplar has been practiced from time immemorial, and has contributed to a stable and highly productive agricultural economy.

The cultivation of poplar in lines today constitutes the most promising technical and economic means of achieving the necessary symbiosis between trees and herbaceous plants.

This form of poplar growing has not, however, been equally well received even in different regions of the same country, and the peasants have sometimes proved hostile or reticent toward its introduction. Propaganda has been carried out to show them that the alleged disadvantages are either nonexistent or can be mitigated by improved planting techniques, and that, on the contrary, it can be beneficial to the region as a whole.

Opinion is divided among agriculturists as to the economic benefit of line plantings. Their evaluations vary according to their interests in the land under cultivation. Hostility comes from the farmers who, since the timber reverts to the landowner, see trees merely as competitors for the soil. Similar interests inspire hostility in neighboring landowners.

Other grievances are often put forward, such as damage to crops from shade, the spread of poplar roots, which extract nutrients and water from the soil along a strip of land roughly parallel to the tree line, and falling leaves and " cotton " from female poplars on pastureland, as well as the blocking of drains.

It can be argued that the lower yield from the adjacent land strip is compensated by the increased yield from the areas beyond the strip which enjoy improved climatic conditions. During the early years of the planting its shade is on the whole beneficial. Poplars break the force of the wind and thus help to keep the soil moist. Hence, what may be counted a deficit for some strips of land may be set against the benefit to the region as a whole.

The disadvantages can be further reduced by planting poplars with rather narrow crowns, by spacing more widely (5 or 6 meters is the minimum), by the use of fertilizers and, if possible, by planting the rows in a north-south direction, thereby minimizing the effect of shade. Planting in this direction, moreover, will provide shade for cattle during the hottest hours of the day. The inconvenience of " cotton " can be overcome by planting male poplars.

In Germany, it is suggested that the marginal land between poplars and crops be given a double dose of fertilizer; the poplar will then spread its roots in a smaller circle. According to observations also made in Germany, poplar leaves make quite good forage; the butter even acquires an individual but pleasant flavor and keeps better in summer.

If there is collaboration between farming and poplar growing, farm labor can be used as available for operations such as trimming, pruning and felling. Timber production constitutes a stable element of revenue, and sometimes helps to counteract the effects of bad harvests by making an additional contribution. In poplars the farmer has, in fact, the means of protecting, or of partly reconstituting the " farm forest," which is his source of fuelwood or of timber for his own needs, and a means of increasing the revenue from his land. Line plantings can constitute for the peasant a sort of " savings bank," or provide dowries for his children. In many regions, each birth is marked by planting a row of trees.

In roadside plantings along public highways the poplar is generally recognized as the most suitable species and the least prejudicial to their upkeep.

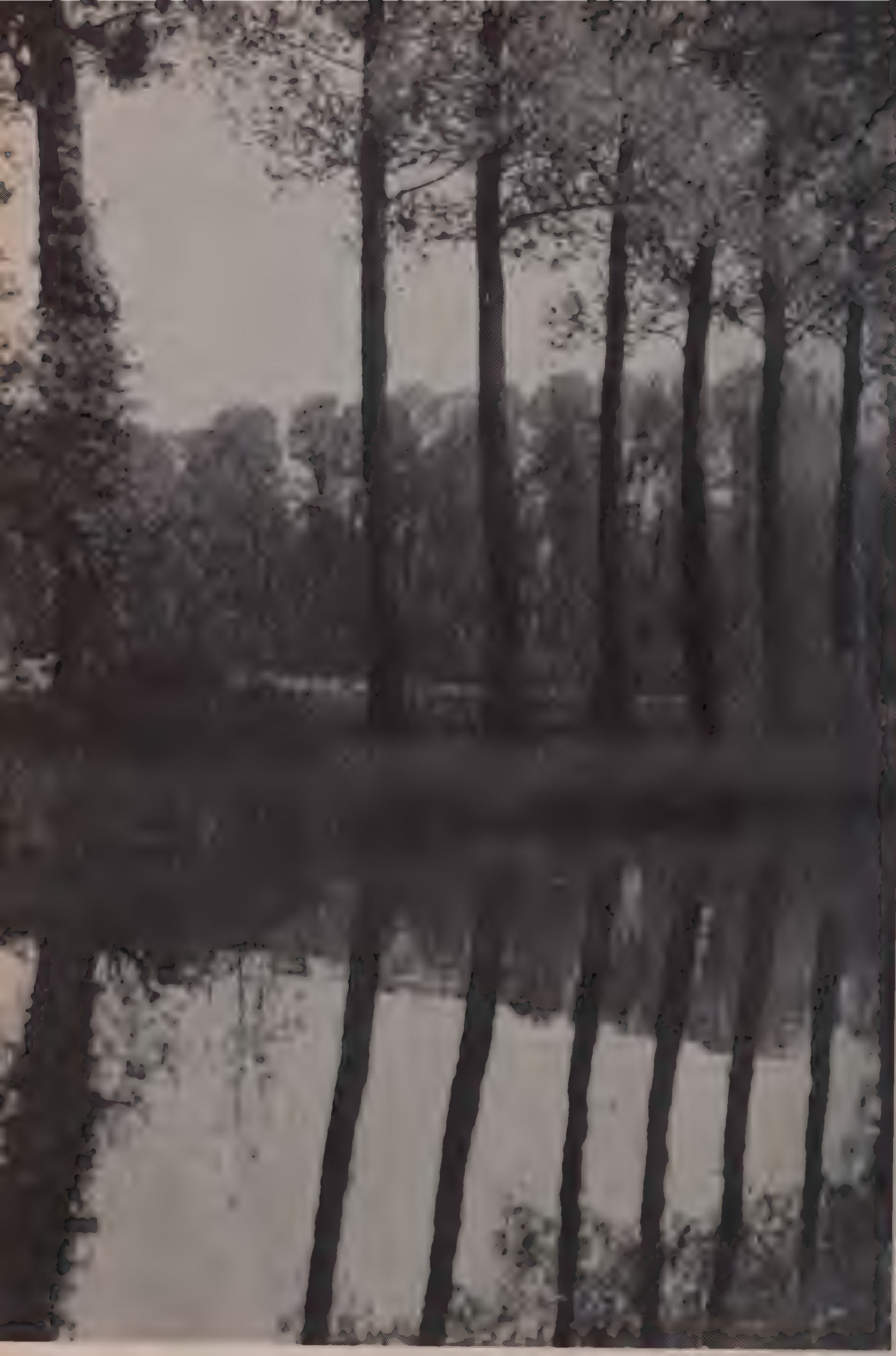


FIGURE 84. – A plantation of *P.* x *euramericana* cv. 'serotina' alongside water at Erft, Germany.

Courtesy R. G. Fontaine

SITE

The site requirements of line plantings are the same as those described earlier, that is to say, plantings are most economically situated:

a) in the vicinity of water — near watercourses, canals, streams, rivers, ponds, drains or irrigation ditches;

b) along highways and roads, as borders for fields under cultivation, and as grassland enclosures;

c) in shelterbelts.

Planting near to water

Here the poplar often finds its ideal habitat. Running water at root level, besides supplying the tree with nutrients, is one of the chief factors in ensuring rapid growth.

Typical examples of this type of poplar growing are to be found in the magnificent rows of poplars which border the large canals of France, Belgium and the Netherlands, as well as the canals and irrigation drains of the Po Valley. In the Near East, the plantings which flank the River Barada, which supplies Damascus with water, also deserve mention.

Another typical example of poplar cultivation on banks is that of the Poitou marsh in France, which yields almost 50,000 cubic meters of timber a year. This produce feeds the large local sawmills and veneer peeling works. The Poitou marsh, which extends over 5,500 hectares, was even as late as the tenth century covered by the sea. Now the so-called " wet marsh " (as opposed to the " drained marsh ") comprises 15,000 hectares and makes perfect poplar site. A system of canals and secondary drains divide it into green pastures and market gardens. Poplars occupy the banks of the entire canal and drainage system, and the whole area is nourished by flood water from the heavy rains in the autumn until the end of the winter. The density of poplar is approximately 45 stems to the hectare, or a total of some 675,000 trees for the whole marsh; nine tenths of these are represented by *P.* x *euramericana* (Dode) Guinier cv. ' serotina du Poitou ' which, at the age of 25 years, attains a circumference at breast height of between 1.60 to 2 meters. The traditional method of propagation has been by sets but in recent years planters have tended increasingly to use selected nursery stock. It can be said that poplar growing on the marsh is in fact becoming intensive.

As an example of canal planting in towns, Paris, with almost 80 kilometers of plantations along the Ourcq canal, deserves mention.

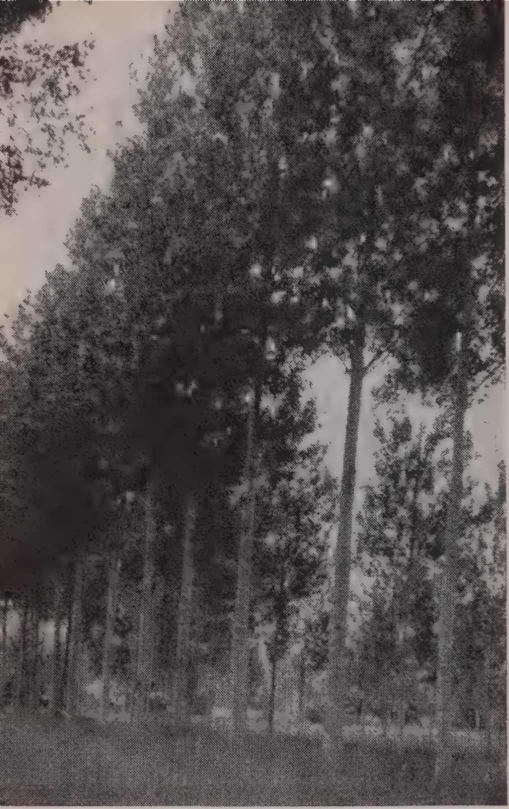
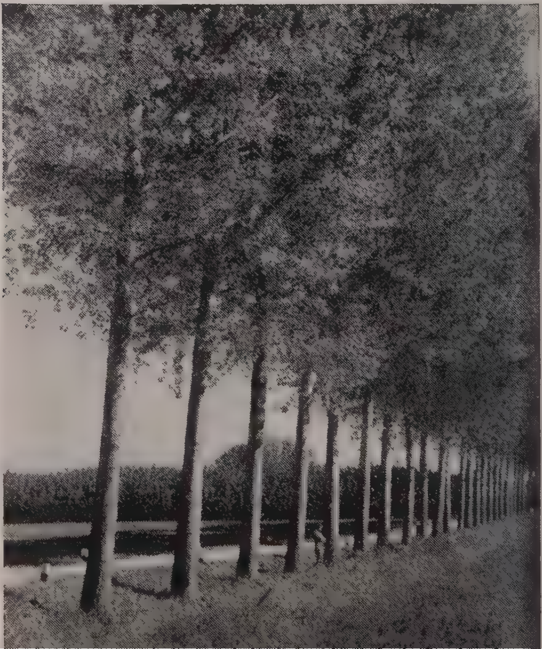


FIGURE 85. – A line of poplars growing on grassland in the Loire Valley, France.

Courtesy *J. Pourtet*

FIGURE 86. – A roadside planting of 13-year-old *P.* x *euramericana* 'I-455' near Casale Monferrato.

Courtesy *Istituto Casale Monferrato*



The cultivation of poplar on banks is less harmful to the bordering land than roadside or field planting, since the crowns spread more over the water than on the neighboring soil. When one bank only is planted to avoid windblow during storms, it is advisable to plant on the bank which receives the brunt of the prevailing wind, since the root anchorage is stronger and deeper on the side away from the water.

In addition, the trees should be planted preferably at a distance of 1 or 2 meters from the bank or edge of the ditch, so that the roots are not exposed by erosion or as a result of their own growth. In certain places which are difficult to plant, sets can be sunk into the sides of the bank in the water to a depth at which they touch firm soil.

Plantings alongside roads and bordering cultivated fields and grasslands

This type of poplar growing has most often met with opposition and mistrust from the peasantry. There are, however, many countries in which it holds a time-honored place and where it has been perfected to the point of becoming a valuable factor in land development. Tree borders are a source of beauty and revenue; they yield large-sized timber, are a stabilizing and protective element in agriculture and, in many regions, have an important — even essential — effect on the climate. Water and other nutrients collected on the road's surface enable poplars to grow well even in apparently unfavorable conditions.

Shelterbelts

Lines of poplars, in addition to their function of producing timber, can also serve as windbreaks. In poorly wooded, or even completely treeless agricultural regions, such windbreaks can be of great value and have a highly beneficial effect on the productive capacity of the region. But in order to be really effective they must be planted systematically for a particular region. This raises an entire range of technical, administrative and economic problems which need first to be examined. For example, wind channelling must be considered in all its aspects. The study of shelterbelts requires the collaboration of meteorologists, soil scientists, agriculturists and trained foresters. The establishment and management of these protective belts should be carried out by authorities representing the various public and private interests, since, just as for row plantings in fields or on grasslands, they should under no circumstances constitute an obstacle to agricultural mechanization.

The width of a shelterbelt is from 15 to 20 times its height, and since the trees should be spaced as widely as possible, they must be at least 20 meters high. The poplar, being one of the fastest growing species is therefore highly suitable, and is often planted for this purpose, particularly in Germany. A shelterbelt can consist of a single row of poplars, provided they are interplanted with another species, such as alder, to prevent gaps where the wind can rush in at increased speed instead of having its force broken.

The trees used for filling in can also be planted as a hedge in the foreground so as to form a sloping contour to deflect the wind upward. Another alternative is provided if the shelterbelt is sufficiently broad to plant one row of poplars down the middle as well as two or three rows of species used for filling in (for example hornbeam, alder or plane). Later, some poplars can be pollarded in alternate rows to strengthen the belt. When the plantation is felled, all protection inevitably ends, so to avoid this, if the belt is broad enough (6 meters), two rows of poplars are planted, separated by two or three rows of the species used for filling. The difference of age between the two rows of poplars is equal to half the age of the rotation. Therefore, if the felling age is 30, the second row will be planted 15 years after the first, and will, therefore, be 15 when the first row is felled.

ARRANGEMENT AND SPACING

Planting distances

Plantings usually consist of single or double rows, more rarely three or four. Since the aim of row planting is to produce large trees, the distance between them should not be less than 4 to 6 meters. Along public highways this spacing can profitably be increased to between 7 and 10 meters, so that the road can drain more easily and the effect of shade and the spread of roots into neighboring property is reduced. Dense or very dense planting, sometimes with a spacing of as little as 1½ meters between trees, is an error both economically and physiologically, except of course if there is a market for small-sized timber. This is the case throughout the Near and Far East, where the trees are used as poles and fetch very high prices. For rows bordering roads and meadows the same planting distances apply but when planting across fields and meadows it is necessary:

a) to plant preferably in a north-south direction for the reasons already given;

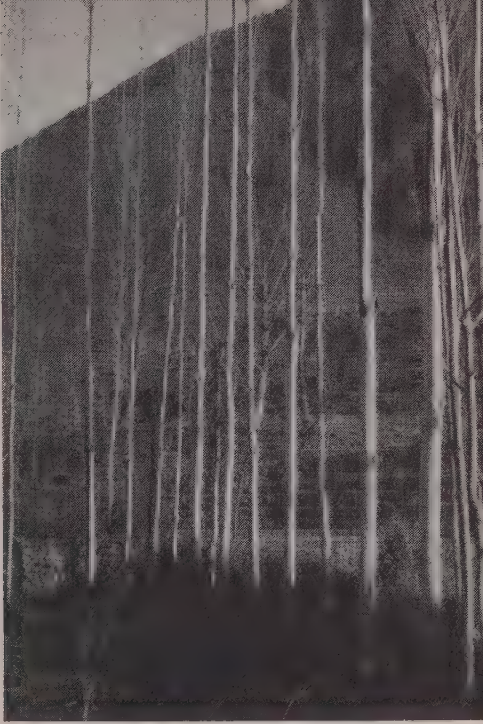
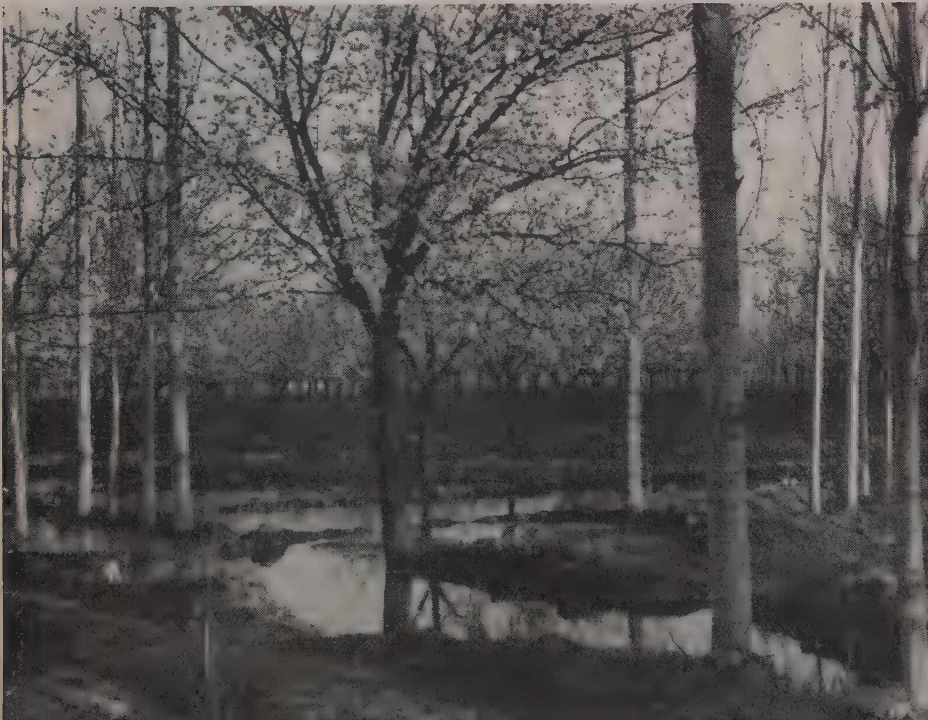


FIGURE 87. – A row planting of poplars near Shrinagar, Kashmir.

Courtesy *G. Giordano*

FIGURE 88. – A poplar shelterbelt in the *ghouta* of Damascus, Syria.

Courtesy *R. G. Fontaine*



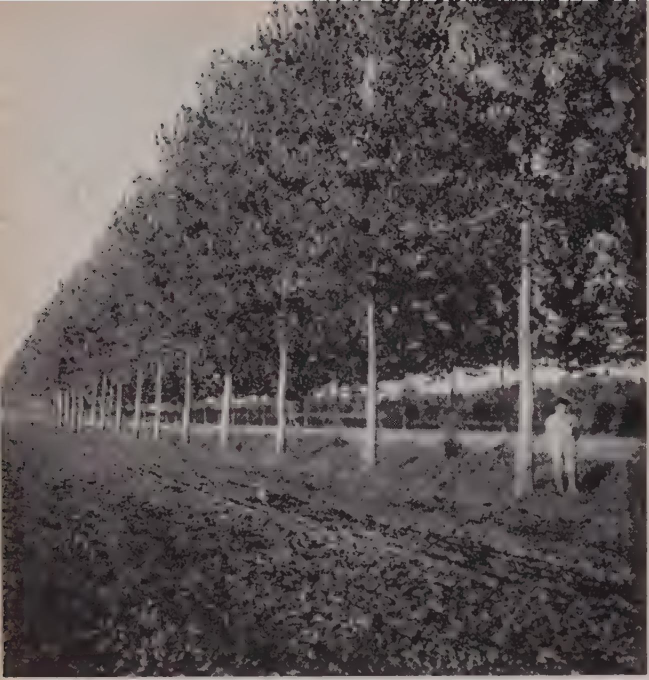
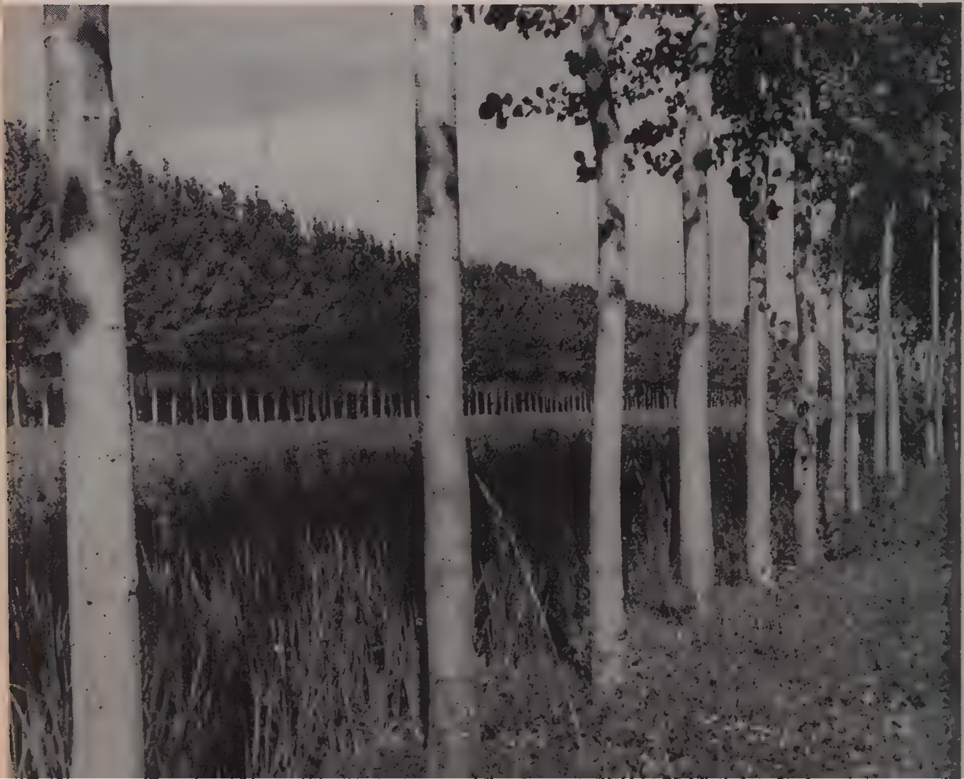


FIGURE 89. – A 4-year-old roadside planting of *P.* x *euramericana* 'I-214' at Marengo, Bergamo, Italy.

FIGURE 90. – A row planting of poplars on grassland at Torviscosa.

Courtesy *Istituto Casale Monferrato*



b) to space wider between trees and rows so as to reduce the effect on the grass or cereal crops. The distance between single lines or, more rarely, between groups of two lines, should be at least 15 to 20 meters. In either single or double lines the distance should not be less than 7 meters;

c) to apply fertilizer to the strips of land running parallel to the lines.

In certain grassland regions of the Netherlands and Germany, it is generally agreed that lines of poplar do no damage provided that there are not more than 25 to 75 trees per hectare of grassland, according to soil quality (25 stems on poor soil, 50 in medium quality soil and 75 in rich soil). An additional product in the form of timber is also appreciated. The distribution of the trees is uniform and at an equal distance in all directions, or the rows are planted in a north-south direction with a spacing of 30 to 50 meters between rows and 10 to 20 meters or more between trees.

PREPARATION OF THE GROUND AND PLANTING PITS

Preparation of the ground

The ground preparation depends on the type of land which borders the row. Sometimes this is simply a bank or fallow ground put to pasture but it may also be cultivated land, and the official regulations and customs which dictate planting distances between property must be observed.

Preparing the planting pits

The pits must be prepared with particular care so as to give the poplar the maximum amount of loose and well aerated soil, since row planting is more often than not carried out in ground which has not been thorougly worked and is often slightly compacted. In the event of a second planting, the hole left when the stump is uprooted can be used again but it is sometimes necessary to remove all vestiges of growth down to the last root. This work is often done by the local peasants who collect this for firewood. The pit is then filled in with well-turned earth and topped with material swept from the road surface. The depth of the turned earth may be up to 1 meter. The breadth of the pit will depend on the soil, the more compact the soil the wider the pit.

PLANTING AND MAINTENANCE

Planting

The methods described for establishing poplar stands are also applicable to line planting. However, the importance, or rather necessity, of using plants which are sufficiently strong and vigorous must be emphasized, as they are more isolated and consequently more exposed to damage and windblow. For the same reason they need to be planted deeper and the soil pressed very firmly into the pit.

Maintenance

It is advisable, if possible, to work the ground from time to time to a certain radius around the base of the tree and, if necessary, to water it.

Pruning must be done with particular care. Unfortunately, in some countries, either from ignorance or intention, the trees are overpruned, leaving the stem practically stripped of branches, on the pretext that it encourages growth and the development of smooth trunks free of blemishes. These destructive practices are usually employed by farmers who wish to limit the shade and the growth of trees which compete with their crops, or to obtain forage for their cattle. Such pruning, far from producing trunks free of knots, stimulates the continual resprouting of epicormic shoots and causes swellings which may well render the stem valueless even for the paper industry, which is the least exacting consumer of timber.

Pruning should be carried out in exactly the same way as for specialized poplar growing, perhaps increasing the proportion of the crown to the rest of the tree. It should be borne in mind that the strong light to which the stem is exposed encourages the abundant sprouting of epicormics.

OVALIZATION OR ASYMMETRY OF THE TRUNK

This defect is particularly common on poplars cultivated in rows, although trees grown in stands are not completely free from it, as has been mentioned earlier.

The causes of asymmetry of the trunk are: uneven distribution of light, lack of balance between the roots and the crown, wind, and curving due to heliotropic and geotropic movements. All these different factors react according to the type of poplar and the conditions under which the plantations are grown, that is to say, site, orientation of the rows and the distance between the trees. The orientation alone is not sufficient to account for this phenomenon. It is the result of the reaction of the tree to the different factors mentioned. This explains, too, why the greatest width of diameter is not always at right angles to the direction of the row. The influence of the different factors varies even in the same row of trees, since the environment may not be uniform, and often the row itself may change direction owing to the conditions of the site. The variable quality and structure of the soil, and even the action of the wind, should also be taken into account. In other words, the planter has only a limited control over the factors which determine asymmetry; he can often do no more than select a type of poplar which is least inclined to it and adopt an adequate spacing.

The following conclusions have been made on the subject of asymmetry from a comparison of results:

- *a*) for the same type of poplar, the percentage of diametrical asymmetry decreases with the increase in spacing between trees;
- *b*) the spacing being equal, the amount of asymmetry is less in poplars with upright or fastigiate habit;
- *c*) asymmetry increases with age.

C. GROWTH INCREMENT

The poplar is a fast-growing species, as has already been mentioned, particularly in relation to the spacing and thinning. This high growth rate is clearly due to the intrinsic qualities of trees belonging to the genus *Populus* but is also attributable to the favorable ecological conditions of the sites where they are usually grown, particularly from the edaphic point of view — deep soils well supplied with water (moist by nature or sometimes artificially irrigated), often improved by cultivation and the application of fertilizers. As a result, by comparison with forest crops generally, which rarely yield more than 10 cubic meters per hectare annually, and for broadleaved species only 5 cubic meters, the yield from poplar stands always appears highly satisfactory, being rarely less than 10 cubic meters and often more than 15, and even 20 or 25 cubic meters per hectare annually.

As an illustration, some data from various countries are given below:

In the *Netherlands*, in 25 years, poplar produces 300 cubic meters per hectare while oak, beech and pine yield respectively 25, 75 and 75 cubic meters.

In *Germany*, in 40 years, on second quality soil, poplar yields as much as 543 cubic meters per hectare, or 5.7 times as much as oak (95 cubic

FIGURE 91. – Group of poplars growing in the gardens at Balbeck, Lebanon.

Courtesy *R. G. Fontaine*

meters) and beech (97 cubic meters); 4.9 times as much as birch (110 cubic meters) and ash (119 cubic meters); 2.7 times as much as spruce (201 cubic meters); twice as much as larch (273 cubic meters); and 1.5 times as much as Douglas fir (366 cubic meters).

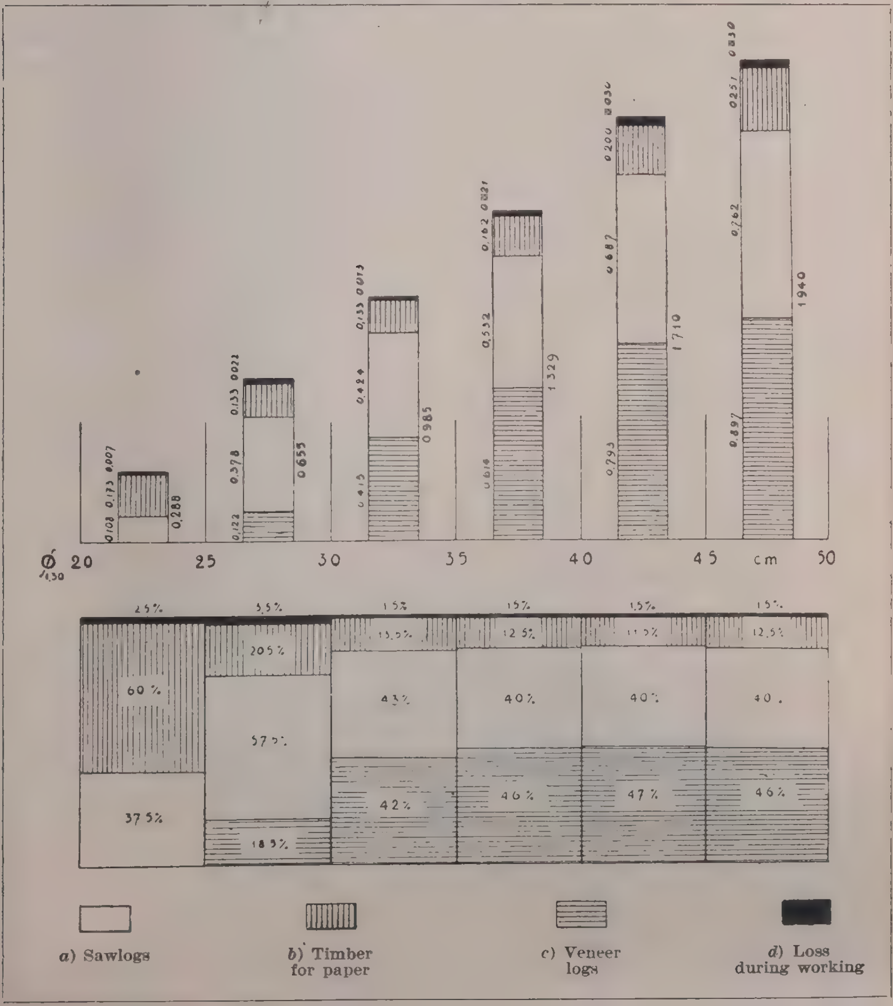
On the island of *Cyprus,* poplar produces 28 times as much as pine and even four times as much as eucalyptus.

However, this growth increment and volume production by unit area are not the only factors to be considered. According to the level of economic development of the region, small-sized timber (that is, with a circumference of less than 80 centimeters at 1.30 meters or even 1.25 meters from the ground) has only a very low market value, or on the contrary is very much in demand.

The striking figures of annual or total production per unit area are therefore insufficient and should be examined in association with the size and unit volume of the tree. A study of their increase in value in terms of time, spacing, site quality, climatic conditions, and lastly, of the clone itself, is particularly interesting.

Results of a recent study in Italy on 150 poplars (Clone ‘I-214’) planted in the Po Valley in deep soil, at a density of 250 stems to the hectare, and combined with agriculture during their early years, are given in the following diagram, which shows the diameters of the different produce classes obtained. Veneer logs have a minimum diameter of 25 centimeters and their percentage of total production remains more or less constant at around 46 percent for logs with a diameter of 30 centimeters and over. This figure is only apparently constant, however, for with larger diameters there is less waste in peeling. In fact, waste accounts for about 5 percent on a billet 45 centimeters in diameter, whereas it accounts for 11 percent where the diameter is only 30 centimeters.

DIAGRAM 1. – PROPORTION OF DIFFERENT PRODUCE CLASSES IN THE TOTAL TIMBER YIELD OF TREES ACCORDING TO THEIR DIAMETER CLASSES AT 1.30 METERS FROM THE GROUND



This is particularly true of the majority of the countries in western Europe, where poplars are only of commercial value and find a ready market if they have a diameter of more than 40 centimeters at 1.30 meters from the ground (circumference, 1.25 meters), which is the minimum dimension, allowing the utilization of an appreciable proportion of their timber for veneer peeling and especially the manufacture of plywood. Since the increment rate at these dimensions is very high, so also is the rate of capital investment.

In all cases, the increase in the value of the average annual increment of the trees over a period can give valuable information for determining the rotation.

Since 1950, the International Poplar Commission has given increment studies a foremost place on its work agenda. These studies have, unfortunately, proved difficult on account of the distribution of poplar stands and the nature of their ownership. The measurements which have been carried out have rarely been in accordance with the statistical methods approved by the Commission in collaboration with the International Union of Forest Research Organizations (IUFRO) for all research work on poplar. The results obtained are thus fragmentary and have only a relative value. The lack of accuracy, frequent in the identification of a cultivated clone, has made comparison between varieties very difficult. However, in certain countries and for certain types of poplar, measurements have been carried out in a sufficient number of stands and in conditions which are varied enough for the data they yield to be of some value. This is the case with *Populus* x *euramericana* 'robusta' in western Europe, an area where large sizes of timber are most in demand and where poplars are frequently associated with pasture or forest species but where they are practically never irrigated or " cultivated " in the agricultural sense.

The data obtained have been summarized in the following tables and the figures then illustrated graphically by curves, representing the circumference increase in terms of time in stands with respectively less than or more than 250 stems to the hectare. The calculations are based on a uniform circumference of 10 centimeters at the time of planting.

Trees in borders have been deliberately omitted from the calculations, as have thinned stands, with a few exceptions, and line plantings have been grouped with stands at the lower densities. No allowance has been made for soil quality, and the curve therefore represents an average.

It is worth noting that the curves " less than 250 stems per hectare " in Graphs I and II can be exactly superimposed; the curves " more than 250 stems per hectare " have a similar shape but the much wider range of spacings studied account for the variations.

TABLE 6. – DATA EXTRACTED FROM DOCUMENT FAO/CIP/50 AND OTHER STUDIES AND PUBLICATIONS OF THE FRENCH NATIONAL POPLAR COMMISSION

Populus x *euramericana* ‘robusta’ - France

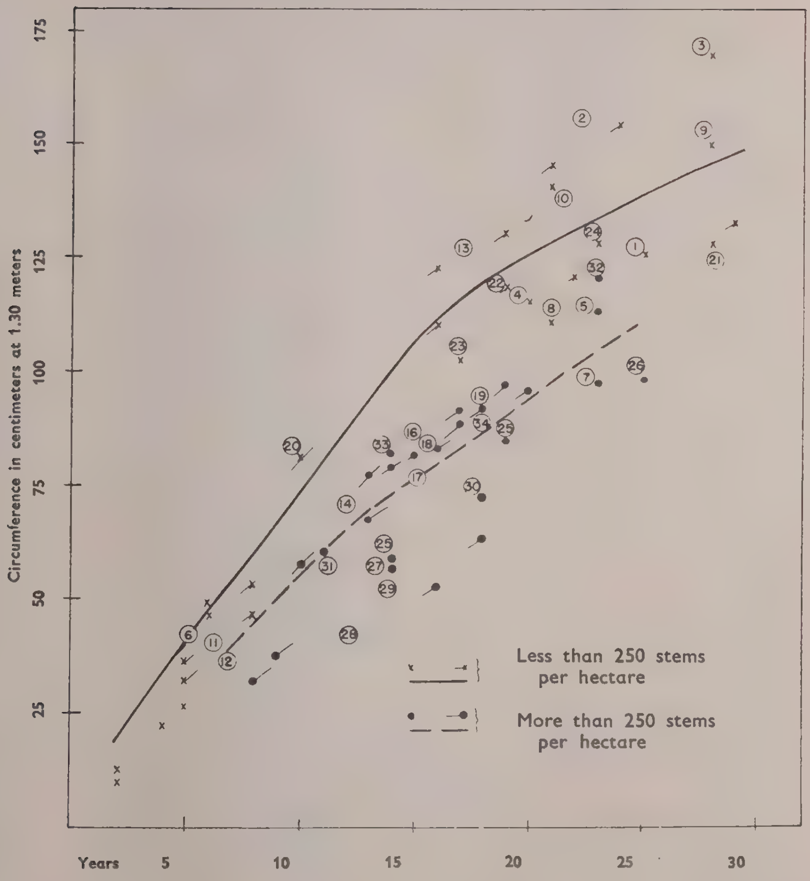
Serial no.	Location of stands	Spacing m.	No. stems per ha.	Age and circumference at 1.30 m.				Annual increment in girth		Remarks
				start of observations		end of observations		average	end of obser-vations	
				years	cm.	years	cm.			
1	Marne Valley	7×7	200	22	120	29	132	4.2 cm.	1 cm.	
2	Marne Valley	8×8	166	21	147.8	24	154.6	6	1.8	
3	Marne Valley (Hte-Marne)	row		28	170			5.7		
4	Marne Valley (Hte-Marne)	7×7	200	20	115			5.25		(canal)
5	Verdun Region	5×5	400	23	113			4.7		
6	Rhine Valley	7×7	200	5	36	6	47	6.2	11	
7	Rhine Valley	5×5	400	23	97			3.8	2.4	
8	Moselle Valley	row		21	110			4.8		(road)
9	Ourcq Valley	7×7	200	28	150			5		
10	Ourcq Valley	7×7	200	21	140			6		
11	Oise Valley	7×7	200	5	32	8	53	5.4	7	(cultivated)
12	Oise Valley	7×7	200	5	26	8	46	4.5	7	(coppice)
13	Oise Valley	7×7	200	16	122	19	130	6.3	2.7	
14	Oise Valley	5×5	400	10	57	14	77	4.8	5	
15	Oise Valley	5×5	400	14	58			3.4		(coppice)
16	Oise Valley	5×5	400	13	77	17	91	4.8	3.5	
17	Seine Valley	6×6	280	13	67	17	88	4.6	5.2	
18	Seine Valley	5×5	400	14	78	18	91	4.5	3.25	
19	Seine Valley	5×5	400	15	81	19	97	4.6	4	
20	Eure Valley	row		6	49	16	110	6.2	3.4	
21	Ouche Valley (Côte-d'Or)	7×7	200	28	128			4.2		(coppice)
22	Saône Valley	8×8	166	19	118			5.7		
23	Saône Valley	8×8	166	17	102			5.4		(dry sand)
24	Saône Valley	7×8	180	23	128			5.1		
25	Saône Valley	5×5	400	19	84			3.9		
26	Saône Valley	4×5	500	25	98			3.5		
27	Saône Valley	4×4	625	14	56			3.3		
28	Rhône Valley (Chautagne)	4×5	500	8	31	16	52	2.6	1 cm.	
29	Rhône Valley (Chautagne)	4×5	500	9	37	18	63	2.9	3	
30	Rhône Valley	4×4	625	18	72			3.4		
31	Garonne Valley	6×6	280	11	60			4.5		
32	Garonne Valley	7×4.5	320	23	120			4.8		
33	Garonne Valley	5×6	335	14	81			5.1		
34	Loire Valley	5×5		14	82.5	18	95	5.3	3.1	
35	Loire Valley	5×5		18	90	22	98	4.5	2	

TABLE 7. – DATA FROM PROGRESS REPORTS OF NATIONAL COMMISSIONS

Populus x *euramericana* ' robusta ' – Germany – Belgium – United Kingdom – Netherlands

Serial no.	Location of stands	Spacing m.	No. stems per ha.	Age and circumference at 1.30 m.				Annual increment in girth		Remarks
				start of observations		end of observations		average	end of observa-tions	
				years	cm.	years	cm.			
1	Belgium	7×5	285	16	94			5.25		
2	Belgium	8×8	166	16	119			6.8		
3	Belgium	8×9	139	17	109			5.8		
4	Belgium	9×9	124	18	121			6.2		
5	Belgium	8×11	114	20	137			6.4		
6	Belgium	7×7		29	140			4.5		
7	Belgium - Bossu	3.9×4	640 480	8	49	17	82	4.25	2.1	(row)
8	Belgium - Bossu	4.5×4.5	495 250	8	54	17	97	5.2	3	
9	Belgium - Bossu	3.6×3.8	730 365	8	47	17	87	4.5	4	
10	Belgium - Bossu	3.6×3.8	730 365	8	49	17	91	4.75	3	(thinned)
11	Belgium - Bossu	3.5×7	245	11	73	15	87	5.1	3.4	
12	Belgium - Bossu	6×6	280	6	36	14	91	5.8	5	(match industry: 7 to 19)
13	Belgium - Debihan	6×6	280	5	29	15	89	5.3	4.4	
14	Belgium - Hainin	3.7×3.7	730	8	41	18	68	3.2	2	
15	Belgium - Hainin	4.8×4.6	455	8	55	17	80	4.1	2.4	
16	Belgium - Hainin	6.5×7	220	17	109	19	113.5	5.4	2.4	
17	Belgium - Hautrage	3×3	1,100	4	20.5	6	34.5	4	6.6	
18	Belgium - Hautrage	4×4	625	4	20.4	6	36.8	4.5	8.8	
19	Belgium - Hautrage	6×6	280	4	24	6	46.1	6	9.7	
20	Belgium - Dongelberg	6×6	280	4	26	14	101.6	6.5	6.3	
21	Belgium - Aarschot	9×9	124	14	108	20	120	5.5	2.8	(coppice)
22	Germany - Ems	3×3	641	12	75			5.4		
23	Germany - Warendorf	6×6	326	13	75			5.4		(rich soil)
24	Germany - Evenwinkel	3×4	832	15	75			4.3		
25	Germany - Evenwinkel	5×5	360	25	132			4.8		
26	Germany - Dingden	5×5	400	17	101			5.3		
27	Germany - Cologne	4.4×4.4	528	13	50			3.1		
28	United Kingdom - Bagley Wood	3×4	832	10	58			4.8		
29	United Kingdom - Bagley Wood	3×4	832	9	51			4.6		

GRAPH I. – FRANCE: *P.* x *euramericana* ' robusta '



In practice, these curves show that trees planted at a density of over 250 (and more often 300) stems per hectare only reach the economically desirable felling dimension of 1.25 meters in circumference at 1.30 meters from the ground (diameter 40 centimeters) in exceptional cases.

In the few cases where the stands have been observed over several years, useful information has been obtained from a comparison of current increment with average increment. Current increment reaches a peak between the sixth and twelfth year and then decreases at a rate proportional to the density of the stand.

These observations which were carried out on *Populus* ' robusta ', a clone easy to identify and widely distributed among young poplar stands of western Europe, may not all be valid for the other poplar types at present under cultivation. It seems to be an established fact that certain types have a rapid growth rate from an early age but show a regression relatively early and are overtaken by others whose growth rate up to this point has been on the slow side. *P.* ' robusta ', for example, belongs to the group of poplars with a high initial growth rate and is therefore suitable for early felling, whereas *P.* 'serotina' has a fairly slow growth rate at first and later shows its superiority up to the age of 35 or 40 years. The same applies to another Euramerican hybrid, *P.* ' regenerata '.

GRAPH II. – BELGIUM, THE NETHERLANDS, GERMANY: *P.* x *euramericana* ' robusta '

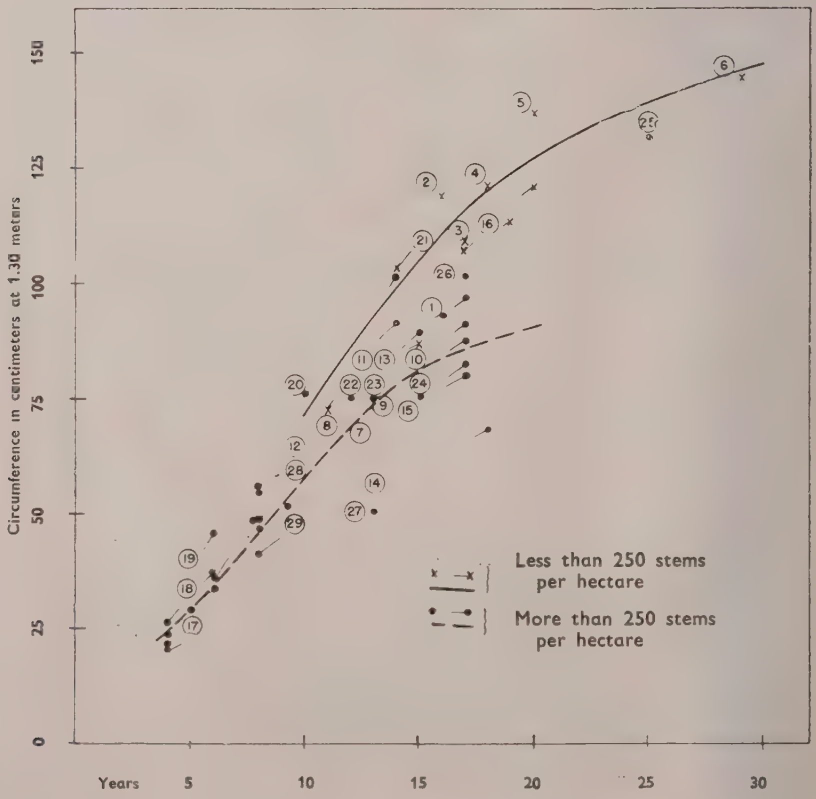
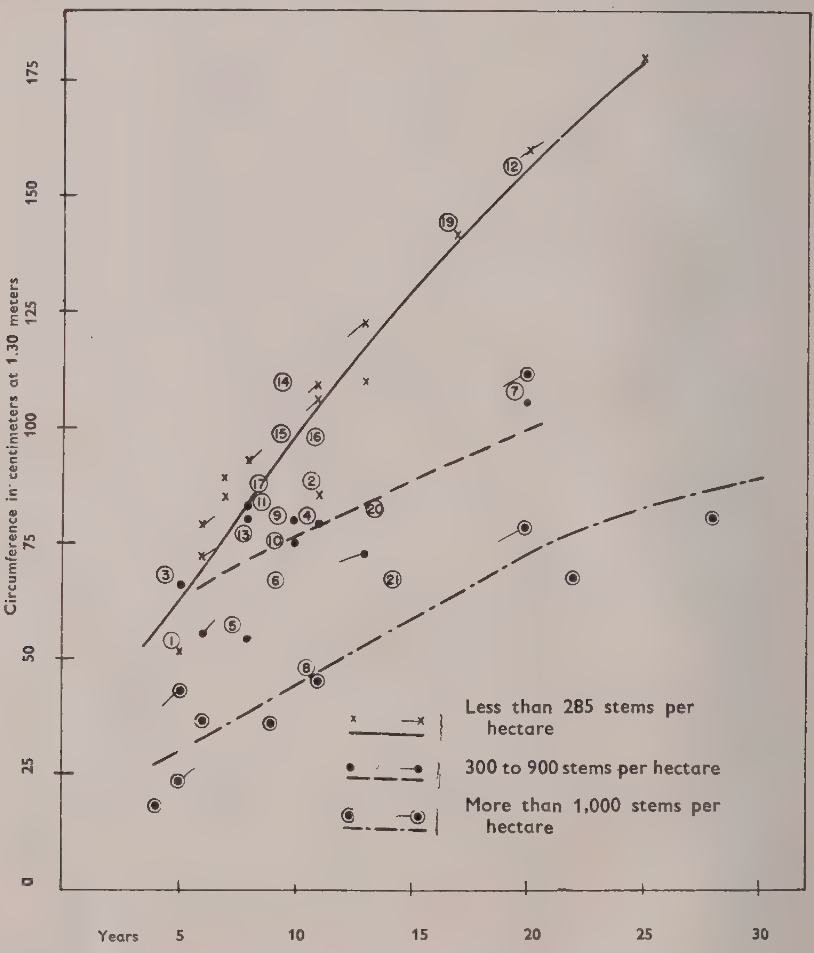


TABLE 8. – DATA FROM DOCUMENTS PREPARED BY NATIONAL COMMISSIONS OR FOREST SERVICES

Various types of poplars grown in cultivated and often irrigated land in the Mediterranean area (Cyprus, Spain, France, Italy, Syria)

Serial no.	Location of stands	Spacing m.	No. stems per ha.	Age and circumference at 1.30 m.				Annual increment in girth		Remarks
				start of observations		end of observations		average	end of observa- tions	
				years	cm.	years	cm.			
1	France - Garonne Valley	10×4	250	5	51			8.2 cm		
2	France - Garonne Valley	6×6	280	11	77			6		
3	Spain - Arzobispo	4×4	625	5	66			10.6		
4	Spain - Hostalrich	5×5	400	11	79			6.3		
5	Spain - Hostalrich	5×5	400	8	54			5.5		
6	Spain - Logrono	3,5×3,5	820	6	55	13	72	4.75	2.5	
7	Spain - Logrono	4×4	625	20	105			4.75		
8	Spain - Santa Fé	2×2	2,500	11	45			4		
9	Spain - Bordils	5×3.9	515	10	80			7		
10	Spain - Bordils	5,5×3.3	550	10	75			7.5		
11	Spain - Bordils	5×5	400	8	83			9		
12	Italy - Po Valley		250	8	92.5	20 25	160 180	7.5 6.75	4.1 3.1	(FAO/CIP/15): Nos. 12 to 17
13	Italy - Po Valley		400	8	80	20 25	120 129	5.5 4.75	2.1 1.6	
14	Italy - Po Valley	3,5×10	285	7	89	13	122	8.6	6.3	(I-214)
15	Italy - Po Valley	3,5×10		6	79	11	109	9	7.6	(I-214)
16	Italy - Po Valley	3,5×10		7	85	13	110	7.7	4.7	(I-455)
17	Italy - Po Valley	3,5×10		6	72	11	105.5	8.7	6.8	(I-455)
18	Italy - Po Valley	3,5×9	315	6	63			8.8		(I-214)
19	Italy - Po Valley	3,5×10	285	17	141			7.7		
20	Cyprus	1×1	10,000	5	43	20	112	5.6	2.5	(soil quality I)
21	Cyprus	1×1	10,000	5	23	20	78	3.8	2.5	(soil quality II)
22	Syria - Ain and Figeh	1,20×0.7	12,000	9	36			2.9		
23	Syria - the Ghouta, Damascus	1,25×0.85	10,000	22	67			2.9		
24	Syria - the Ghouta, Damascus	1,5×0.9	7,560	4	18			4.5		
25	Syria - the Ghouta, Damascus	border		6	36			6		
26	Syria - the Ghouta, Damascus	border		28	80			2.8		

GRAPH III. – SOUTHERN REGIONS: TENDED AND IRRIGATED POPLAR STANDS



The scattered information published does not always refer to the same clone under one and the same name, so that observations made by foresters can neither be confirmed nor refuted. This information, nevertheless, provides data which can be translated graphically into curves comparable to those obtained for *P.* 'robusta', but it is clear that the increment of forms with spreading crowns, less upright than 'robusta', is more affected by higher densities in stands.

Lastly, the annual growth cycle shows variations according to type: some start their growing season very early and finish growth early, while others finish their growing season much later. They can, therefore, use to a greater or lesser degree the potential growing season, and their relative annual increment will be strongly affected by climate and region.

In the countries of southern Europe and western Asia, conditions are quite different. The stands are very dense, generally irrigated, and yield the produce classes of timber which are in demand. Information on these stands is relatively scarce and rarely applies to clearly defined types cultivated in pure stands. It is certain, moreover, that in very dense plantations the influence of the clone is of less importance than its growing conditions. This is illustrated by the figures summarized in Table 8 and Graph III; in the latter the curves represent the circumference increment in terms of time, in stands with respectively less than 285 stems per hectare, with 300 to 900 stems and with more than 1,000 stems.

These curves have been extrapolated to 20 or 25 years, although it is very unusual for the trees to be left standing for more than 20 years and, in the more southerly regions, 15 years.

To convert the circumference or diameter measurement of a tree into its total cubic volume, a double-entry scale of volumes is used in which the volume is expressed in terms of the height and of the growth decline. The latter varies considerably according to the type, the kind of planting (group plantation, in lines), density, etc. It seems that this decline varies from 3 to 6 centimeters per meter of the circumference.

As an illustration three volume scales are given in the appendix; they were published respectively in France, Italy and in Cyprus.

D. Economic aspects

It may be useful to conclude the section on intensive cultivation with a few observations on the compilation of a balance sheet for poplar cultivation.

These observations will, however, be restricted to setting out some general principles which hold good everywhere as a basis for calculation, then to examine some actual examples for different types of cultivation and different markets. No attempt will be made to draw firm conclusions from the balance sheet as to the best methods of cultivation to adopt. In fact, in view of the difference in market requirements, according to the region, for the various products, the extent of the forests, the agrarian structure, and the degree of association with agricultural crops or pasture, each case must be judged on its own merits.

It is nevertheless necessary to recall here the general influence of spacing and thinning on the financial revenue from the planting, the two aspects of which — the physiological and the economic aspect — were discussed at the beginning of this chapter, and their dependance on the important role played by the market, that is to say, the degree of industrialization of the region, in determining the spacing to adopt and, consequently, the rotation.

Without reconsidering the question of spacing, it may be helpful to add some remarks on the felling age, which is closely linked with spacing, and which may clarify the matter.

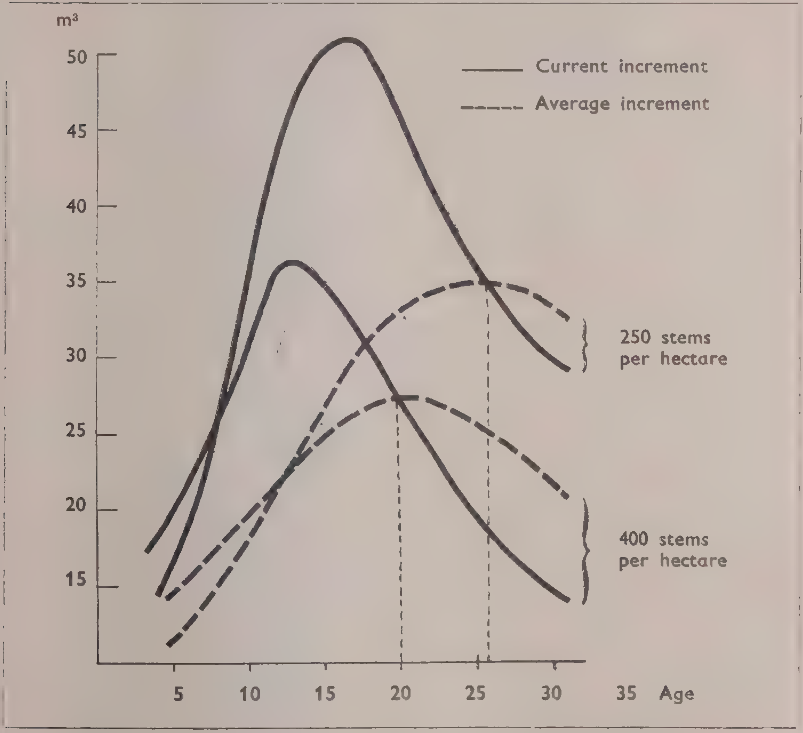
If one examines the volume increment curve for a particular region, for example the Po Valley, in order to determine the rotation which gave the highest timber yield, it can be seen that the average increment curve intersects the current increment curve (corresponding to the maximum timber production), at approximately 20-21 years for dense stands and over 25 years — probably around 26-27 years — for open stands (Graph IV).

The rotation thus determined, corresponding to the maximum average increment is not, however, the one which is most often followed by poplar growers, any more than the rotation which yields produce having the highest average unit price on the market, or that which takes into account not only the price but also the maximum quantity of produce yielding the highest gross revenue. The growers are concerned rather with the rotation which will yield produce suited to specific uses and which are thus financially advantageous, or better still, a rotation which takes account of both the gross revenue and the cost of production, and which derives the greatest profit from the soil.

Needless to say, a great deal of data are necessary in order to determine a suitable rotation for each particular case, but a comparison of the two curves mentioned will indicate the influence of the economy upon the questions of spacing and felling age.

If the two curves are applied to the same region — in this case the Po Valley — it will be observed that the plantations with the highest density predominate in areas where there are few industrial consumers of large sizes of produce but where there are, however, industries which can profitably use small sizes. This is the case in the lower Po Valley where poplar growing is still relatively undeveloped. In the upper Po Valley, on the contrary, where an older tradition of poplar growing has given rise to important and highly developed industries requiring larger sizes of produce, wider spacings and higher felling ages are to be found.

GRAPH IV. – CURRENT AND AVERAGE INCREMENTS PER HECTARE OF TWO POPLAR STANDS IN THE PO VALLEY – ONE WITH 400 STEMS TO THE HECTARE AND THE OTHER WITH 250 STEMS TO THE HECTARE



In fact, information collected by SAIA, for a study on the economics of poplar growing, yields the following figures, which give some idea of the degree of industrialization in the three areas:

1. Upper Po Valley – number of poplars per hectare: 266
2. Middle Po Valley – ” ” ” ” ” 365
3. Lower Po Valley – ” ” ” ” ” 391

These densities give, respectively, the following yield figures:

Region	Average weight of felled trees (in quintals)	Annual yield per hectare
Upper Po Valley	7.26	146 q. = approx. 18 m^2
Middle Po Valley	4.72	138 q. = approx. 17 m^3
Lower Po Valley	2.81	130 q. = approx. 16 m^3

It will be noted that these figures are lower than those of good stands in the upper Po Valley, on which the curves mentioned above were based, and show that a simple improvement in the techniques could increase the output from existing stands.

In Middle East countries, where the degree of industrialization is lower, poplar growing has as its objective the production of small sizes of produce for which there is a market, with therefore denser plantations and shorter rotations; such a policy is also encouraged by the ecological conditions. In France, Belgium and the Netherlands, on the other hand, where the degree of industrialization is higher, spacing is proportionately greater and rotations longer. This is not solely a result of ecological conditions but also of the nature of the market, where there is no demand for small sizes of produce, whereas there is a high demand for large-sized timber.

Market conditions in Italy and Yugoslavia fall somewhere between these two extremes, as do planting density and crop rotation, always taking into account the ecological features of the environment.

It is therefore clear that the solution to the question so often raised on crop rotation and density depends largely on economic considerations. Increment data, which should also be interpreted in relation to the ecological conditions of the region, cannot alone provide the answer to problems whose importance varies according to the market. They do, however, set the limits within which it may be technically possible to find a solution to local problems. Comparisons between regions which do not fall within territorial limits having similar economies are not valid, and experimentation, if it is to be of any value, must take into account these geographical limits, since the declared aim of intensive poplar cultivation is always to attain the maximum economic profit.

Finally, in discussing the compilation of a poplar balance sheet, no account will be taken of the general benefits which invariably accrue from poplar cultivation to the country as a whole, but which vary from one country to another according to its economic development, agrarian structure and demographic status. These benefits consist principally in supplying artisan and other industries with the products currently in greatest demand; in providing work which will absorb manpower during the stages of timber production and extraction as well as during the various phases of conversion, both primary and secondary; in the intensive utilization of the soil which will increase the profit from the land, and in improving the living standards of the people concerned.

General principles

Examination of the different forms of intensive cultivation will already have shown that there are two extreme cases, depending on whether agricultural crops play an important part in it or not.

Plantations of the first type established on marginal land, which has, generally been abandoned for agricultural purposes, yield timber products only — apart from a little pasture and forest litter — and are only indirectly associated with agriculture, mainly in that they share the same manpower. This is true of the immense plantations which are to be seen in the valleys of western or central Europe, on land which is often flooded and therefore unsuitable for agriculture.

Plantations of the second type, established on agricultural land proper, are associated first with crops, then pasture, and are closely linked with the agricultural economy by virtue of the mutual benefit derived. If, in fact, the crops benefit from the environment created by the trees, the poplars for their part have the advantage of the cultural practices, manuring and the labor intended primarily for the cultivation of crops. Moreover, poplars may either be grown in large or small commercial plantations, combined with crops for the first few years and with pasture or hay crops for the first few years and with pasture or hay crops (the most usual accessory to agriculture) in later years, or they may be grown in lines between cultivated fields or along country roads and canals. Such plantings are common in southern Europe.

In practice, plantations are generally a compromise between these two extremes and therefore come, to a varying degree, under agricultural or forest management, according to the importance allotted to agriculture. Poplar growing with its periodic crops of primary products, which derive from a timber " capital " accruing at compound interest and which share the same market as other timber produce, comes under forest management. On the other hand, by the application of cultural practices, manuring protection against insects and diseases and the supervision that it requires, it is akin to the agricultural economy.

Needless to say, these various considerations should not be allowed to obscure the fact that there still exists in all countries, to some extent, the small-scale planting of poplars in borders or in small groups, which is of great importance both from the rural as well as the national point of view. The cultivation of small groups constitutes a form of saving which is more remunerative, safer and more convenient than deposits to the bank. In this case, planting is done by the farmer himself with material often originating on the farm (cuttings), the trees are tended as and when agricultural labor is available, and they benefit from the applications of fertilizers applied to the crops. Apart from a slight decrease in the area under crops, often, however, compensated for by an increase in yield, the periodic revenue from the sale of timber realizes an important profit in view of the low production costs. Such profit, as has already been seen, can help to meet additional family expenses, such as dowries, or property expenses, such as investments.

To conclude, whatever the degree of association with agriculture, it can be said that the determining factors in the compilation of a balance sheet for poplar cultivation, or in establishing the net cost of timber production, are as follows:

1. Poplar growing is very often an agricultural activity, not only because of the environment in which it is practiced, the methods and techniques which it employs and the technical knowledge that it requires, but also because of the economic system to which it belongs. Since it belongs, in effect, to the agricultural economy, its development should benefit from all the other activities connected with agriculture and adapt itself to them. Therefore, it is difficult to regard poplar growing as a form of cultivation except for the purpose of determining the net cost, which must take account of all operations entering the agricultural economy.
2. The compilation of a balance sheet must take into consideration the utilization of the end product. This is a technical as well as an economic problem. Poplars can yield veneer logs, logs for sawing and wood for the paper industry. Therefore, even when the timber possesses identical technical qualities, the aim should be to obtain a balance between these three products in order to obtain the highest financial profit, the greatest elasticity in production and the most reliable and varied outlets.
3. Labor costs may constitute a more or less heavy item in the cost of production; this will depend largely on whether it is possible to adopt a program of work which makes the best use of the manpower available. In fact, it may only be possible for the landowner who has the necessary manpower at his disposal at the right time, and at a moderate charge, to give the planting the care upon which its success may depend. Such tending is made possible by combining poplar growing with agriculture.

4. Lastly, the item " capital " is a very important one. In establishing a poplar stand, " capital " in the form of timber is invested in the ground. This capital may be important in relation to the land value, the interest charges on which may become more or less heavy, depending on how the establishment is financed and on the revenue derived from secondary products. These charges should be calculated as accurately as possible and conform as nearly as possible to actual developments. This is all the more important in that actual expenses are frequently higher than anticipated as a result of misfortunes which necessitate preventive measures, direct measures, etc., or in the event of unavoidable losses.

With these general principles in mind, a balance sheet for poplar growing can be drawn up along the usual lines. Since without close association with agriculture this presents no difficulties, the emphasis here is on the type of balance sheet where poplars are grown in conjunction with farm crops. An analysis of the different operations involved in a combined economy indicates the factors which must be taken into account in the various items of the balance sheet, and the difficulties which will arise in costing special cultivation measures.

Intensive poplar growing in fact requires certain cultural practices which vary according to the environment, the degree of intensity and association with farm crops. These practices, which have already been described, are as follows:

a) ground preparation and digging the planting pits;
b) planting;
c) cultural practices;
d) manuring;
e) planting of replacements;
f) trimming and pruning;
g) irrigation and drainage;
h) anti-parasite control measures;
i) felling and utilization.

All these operations can, of course, be carried out by manpower, materials and equipment especially intended for poplar cultivation, or by outside contractors for the last operations, felling and utilization. It is, however, obvious that they can be effected more economically under technically better conditions and at the most convenient seasons with the help of agricultural manpower and implements.

Ground preparation, pit digging, planting, replacing failures, trimming and pruning, felling and utilization can in fact be performed in conditions which are technically and economically better, and at the seasons which are most likely to ensure their success, if agricultural manpower and equipment are used. These operations can usually be carried out when they do not clash with farm work, and are thus a valuable asset to the distribution of work throughout the year. The repair of equipment will also be carried out under the best conditions.

Combination with farm crops during the early years after planting — thereby enabling more thorough soil preparation while meeting part of the expenses, and at the same time helping to increase productivity — is facilitated if agriculture is already established on the land, in which case the financial success of the joint enterprise is ensured, although it may not be easy to assess their costs separately.

Manuring and *irrigation* will benefit poplars and crops alike. Due to manuring, carried out during the first four years of the rotation, in a poplar stand combined with crops in the Po region, the timber yield has doubled. It is nevertheless difficult to estimate the proportion of the manuring costs which should be charged to the poplars when drawing up separate balance sheets.

As regards irrigation, poplar growing is frequently an economic proposition only where a well-planned network of canals and ditches already exists. Naturally, irrigation, while it increases the timber yield, involves the crops in a certain amount of loss. The trees can be irrigated separately but such a practice is costly and is only done in exceptional cases. In any event, it is still difficult to make individual assessments of the irrigation required to meet the respective needs of crops and trees.

Anti-parasite control measures are at present almost as important for poplars as for farm crops. A number of clones are known to have adequate resistance to certain serious diseases but direct control measures are still needed to combat other enemies of poplar. Very often it is not sufficient to take measures on a single land holding; to be really effective, control needs to be extended to several such holdings covering a sufficiently large land area. This applies particularly in the case of xylophagous insects or defoliators, whose attacks impair the quantity and quality of the timber produced. The organization of collective control measures is simplified if labor is available on the spot, for the control of parasites must be carried out at once if it is to be successful.

Clearly, therefore, where intensive poplar growing is associated with agriculture, their cultural practices too are closely linked, and it would be difficult to evaluate the assets and liabilities of each operation in a separate account without making a more or less arbitrary distribution of expenses.

A true evaluation is more likely to result from a complete examination of the balance sheet of the joint economy, and this is therefore the type of balance sheet that should be drawn up. While there are various types of balance sheets, in theory the general layout is as follows:

Liabilities

a) cost of land usage (rent, or interest on the purchase price of the land);
b) labor costs;
c) purchase of floating assets (seeds, plants, etc.);
d) depreciation, maintenance and insurance of fixed assets (buildings, machinery, cattle, etc.);
e) duty and taxes;
f) cost of maintaining a reserve and working capital;
g) administration and supervision.

Assets

These consist of the products for sale, that is, total yield minus those products which are used again on the property (forage, litter, seeds, etc.).

Comparison of balance sheets for different poplar plots or between those for a single agricultural unit, whether cultivated in conjunction with poplars or not, can show the different objectives of cultivation.

Analysis of the " liabilities " and " assets " can be more or less thorough depending on the ultimate objective, but in every case it should be stated whether actual figures are given, that is to say, costs for operations actually performed, or estimated costs on the basis of over-all expenses. In the case in question, the most important items of the balance sheet are:

Liabilities

a) cost of ground and planting pit preparation;
b) cost of planting stock;

c) cost of planting and of replacements;

d) cost of cultural practices and pruning;

e) cost of anti-parasite measures;

f) cost of depreciation and maintenance of machinery and implements used only for poplars;

g) cost of technical management, administration, supervision, etc.

Assets

a) revenue from agricultural produce;

b) revenue from the sale of products derived from pruning and thinning;

c) revenue from the final crop of standing timber, estimating if possible the respective percentages of veneering timber, saw logs, timber for matches, pulpwood for paper, timber for small industries (small packing cases, wood wool, wood flour, sabots, toys, etc.) and firewood.

By drawing up balance sheets in this way, poplar growers can compare accurately the different methods of cultivation and, accordingly, take decisions for the future.

Analysis of some particular examples

Among the documentation submitted to the Secretariat of the International Poplar Commission are balance sheets concerned with poplar cultivation, some of which are reproduced or analyzed below.

Netherlands

Professor G. Houtzagers has supplied the International Poplar Commission with economic data on border plantings which are of great importance in his country. These figures are given in Appendix 2.

Production costs have been calculated on the basis of standard prices and yields, and all items included in the over-all cost have been estimated on the basis of 1955 prices and not on the average over a certain number of years. This method is justified if the forest administration is to be a profitable undertaking. Considering both the soil and the forest as a safe, long-term investment, valued at a lower rate of interest than state bonds (3 ¼ percent), a 3 percent rate of interest was chosen and calculated at compound interest.

Spain

Poplar cultivation on the banks of the River Genil, in the region of Granada was the subject of the paper submitted to the Eighth Session of the International Poplar Commission. Poplars have been grown here for centuries and have contributed to a continual improvement of the soil. The plantations, which are composed chiefly of two clones (*P. nigra* cv. ' Blanquillo de Granada ' and *P. euramericana* cv. ' Negrito '), occur on diluvial ground. They are worked on rotations of from 8 to 16 years and are combined with crops for the first two years. The rotation is shortened or extended, depending on the market requirements for wood in the round or sawn timber, the longest rotations giving diameters of from 12 to 18 centimeters. Shorter rotations yield 85 percent wood in the round and 15 percent sawing timber, while the longer rotations yield respectively 40 and 60 percent.

In the note reproduced as Appendix 3, the authors, Messrs. José and Eduardo Rojas, have determined the exploitable age which gives the highest revenue from the land. In this particular case no account has been taken of the price differences between different produce classes of timber; small-sized wood in the round is very much in demand at present and has even led to shorter crop rotations.

France

Poplar growing in the north of the country is not closely associated with agriculture — in fact, the association is only an indirect one and principally affects manpower. Maître Chaton, a notary of Troyes and member of the French National Poplar Commission, has compared yields of the same clone in different plantations and on sites having a varying degree of fertility. His estimates apply to *P. deltoides* cv. ' virginiana ' for plantations felled at 25 years and having a spacing of 8×8 or 9×9 meters. A study of the relationship between initial assets and assets after felling shows that in the particular case of the Aube region, where there is a market for good quality veneer logs and saw logs, only plantations on good soil capable of producing stems of the required dimensions in a short time are an economic proposition (Appendix 4).

Italy

Poplar growing is very widespread in Italy, chiefly in the Po Valley, where it is combined with agriculture.

In a report summarized in Appendix 5 and published by Messrs. Piccarolo and Vaccarone of the Poplar Research Station at Casale Monferrato, the author, Mr. Bellucci, has analyzed the expenses of, and revenue from, poplar growing in association with agriculture and has estimated the total market and per hectare value derived from the land. The area consists of 25.32 hectares of agricultural land, 5 hectares of which were planted with Euramerican poplars cultivated in conjunction with farm crops during the first few years and felled at 12 years.

APPENDIX 1

CUBIC VOLUME TARIFF TABLE

a) TARIFF TABLE DESIGNED IN FRANCE FOR WELL-PRUNED POPLARS

(Volume in cubic meters)

By L. Schaeffer

Height of trunk m.	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Circumference at breast height cm.																					
50	0.08	0.09	0.11	0.12	0.13	0.13	0.14	0.15	0.16	0.17	0.17										
60	0.12	0.14	0.15	0.17	0.18	0.19	0.20	0.21	0.22	0.24	0.25	0.26									
70	0.16	0.19	0.21	0.23	0.25	0.26	0.28	0.29	0.31	0.32	0.34	0.36	0.37								
80	0.21	0.24	0.27	0.30	0.32	0.34	0.36	0.38	0.40	0.42	0.44	0.47	0.49	0.51							
90	0.27	0.31	0.34	0.38	0.41	0.43	0.46	0.48	0.51	0.53	0.56	0.59	0.61	0.64	0.66						
100	0.33	0.38	0.43	0.47	0.50	0.53	0.56	0.59	0.63	0.66	0.69	0.73	0.76	0.79	0.82	0.84					
110	0.40	0.46	0.51	0.56	0.61	0.65	0.68	0.71	0.76	0.80	0.84	0.88	0.92	0.95	0.99	1.02	1.05				
120	0.47	0.55	0.61	0.67	0.72	0.77	0.81	0.85	0.90	0.95	1.00	1.05	1.09	1.14	1.18	1.22	1.25	1.29			
130	0.56	0.64	0.72	0.79	0.85	0.90	0.95	0.99	1.06	1.12	1.17	1.23	1.28	1.33	1.38	1.43	1.47	1.51	1.68		
140	0.65	0.75	0.83	0.91	0.99	1.05	1.10	1.15	1.22	1.29	1.36	1.43	1.49	1.55	1.60	1.65	1.70	1.75	1.79	1.83	1.87
150	0.74	0.85	0.96	1.05	1.13	1.20	1.27	1.32	1.41	1.49	1.56	1.64	1.71	1.78	1.84	1.90	1.96	2.01	2.06	2.11	2.15
160	0.84	0.97	1.09	1.19	1.29	1.37	1.44	1.50	1.60	1.69	1.78	1.86	1.94	2.02	2.09	2.16	2.22	2.29	2.34	2.40	2.44
170	0.95	1.10	1.23	1.35	1.45	1.55	1.63	1.70	1.81	1.91	2.01	2.10	2.19	2.28	2.36	2.44	2.51	2.58	2.65	2.70	2.76
180	1.07	1.23	1.38	1.51	1.63	1.73	1.82	1.90	2.02	2.14	2.25	2.36	2.46	2.56	2.65	2.73	2.82	2.89	2.97	3.03	3.09
190	1.19	1.37	1.54	1.68	1.81	1.93	2.03	2.12	2.26	2.39	2.51	2.63	2.74	2.85	2.95	3.05	3.14	3.22	3.30	3.38	3.45
200	1.32	1.52	1.70	1.87	2.01	2.14	2.25	2.35	2.50	2.64	2.78	2.91	3.04	3.16	3.27	3.37	3.48	3.57	3.66	3.74	3.82

APPENDIX 1 (*continued*)

b) TARIFF TABLE DESIGNED IN ITALY FOR VOLUMES OF POPLARS TO A MINIMUM DIAMETER OF 10 CENTIMETERS

(Volume in cubic meters)

Source: *Il Pioppo*, G. Piccarolo, Rome, 1952

Diameter at 1.30 m.	Circumference at 1.30 m.	Height for cubic volume (height to a minimum diameter of 10 cm.)											
		6 m.	8 m.	10 m.	12 m.	14 m.	16 m.	18 m.	20 m.	22 m.	24 m.	26 m.	28 m.
cm.	cm.												
12	38	0.052	0.068	0.086	—	—	—	—	—	—	—	—	—
13	42	0.059	0.078	0.098	0.117	—	—	—	—	—	—	—	—
14	44	0.066	0.088	0.110	0.133	0.155	—	—	—	—	—	—	—
15	47	0.074	0.098	0.124	0.148	0.173	0.197	—	—	—	—	—	—
16	50	0.082	0.110	0.137	0.164	0.192	0.220	—	—	—	—	—	—
17	53	0.090	0.121	0.151	0.181	0.212	0.242	0.272	—	—	—	—	—
18	56	0.103	0.133	0.165	0.198	0.232	0.265	0.298	0.331	—	—	—	—
19	60	0.108	0.144	0.181	0.216	0.253	0.289	0.325	0.361	—	—	—	—
20	63	0.117	0.157	0.196	0.235	0.274	0.314	0.352	0.392	0.431	—	—	—
21	66	—	0.170	0.212	0.255	0.298	0.340	0.382	0.425	0.468	0.510	—	—
22	69	—	0.184	0.229	0.275	0.321	0.367	0.413	0.459	0.505	0.551	0.597	—
23	72	—	0.197	0.247	0.297	0.346	0.396	0.445	0.494	0.544	0.593	0.643	0.692
24	75	—	0.212	0.265	0.318	0.371	0.424	0.477	0.530	0.583	0.636	0.689	0.742
25	78	—	0.227	0.283	0.340	0.397	0.454	0.511	0.567	0.624	0.681	0.737	0.794
26	82	—	—	0.303	0.363	0.423	0.484	0.545	0.605	0.666	0.726	0.787	0.847
27	85	—	—	0.322	0.387	0.451	0.516	0.580	0.645	0.709	0.773	0.838	0.902
28	88	—	—	0.342	0.411	0.479	0.548	0.616	0.685	0.753	0.822	0.890	0.958
29	92	—	—	0.363	0.436	0.509	0.581	0.654	0.726	0.799	0.872	0.944	1.017
30	94	—	—	0.385	0.461	0.538	0.615	0.692	0.769	0.846	0.923	1.000	1.076
31	97	—	—	—	0.487	0.569	0.650	0.731	0.812	0.804	0.975	1.055	1.137
32	100	—	—	—	0.515	0.601	0.687	0.773	0.859	0.945	1.031	1.116	1.202
33	104	—	—	—	0.543	0.633	0.724	0.815	0.905	0.995	1.086	1.176	1.267
34	107	—	—	—	—	0.668	0.764	0.859	0.955	1.050	1.146	1.242	1.337
35	110	—	—	—	—	0.704	0.805	0.906	1.006	1.107	1.208	1.308	1.409
36	113	—	—	—	—	—	0.845	0.951	1.057	1.162	1.268	1.374	1.479
37	116	—	—	—	—	—	0.887	0.998	1.109	1.220	1.331	1.443	1.554
38	119	—	—	—	—	—	0.931	1.047	1.163	1.280	1.396	1.513	1.629
39	122	—	—	—	—	—	0.975	1.096	1.218	1.340	1.462	1.584	1.704
40	126	—	—	—	—	—	1.019	1.147	1.274	1.402	1.529	1.656	1.784
41	129	—	—	—	—	—	1.064	1.198	1.331	1.464	1.598	1.730	1.863
42	132	—	—	—	—	—	1.113	1.252	1.391	1.530	1.669	1.808	1.947
43	135	—	—	—	—	—	1.162	1.307	1.452	1.597	1.742	1.888	2.033
44	138	—	—	—	—	—	1.212	1.363	1.514	1.666	1.817	1.968	2.120
45	141	—	—	—	—	—	1.262	1.420	1.578	1.735	1.893	2.051	2.209
46	144	—	—	—	—	—	1.313	1.477	1.642	1.806	1.970	2.134	2.298
47	148	—	—	—	—	—	1.368	1.540	1.711	1.882	2.053	2.224	2.395
48	151	—	—	—	—	—	1.424	1.602	1.780	1.959	2.137	2.315	2.493
49	154	—	—	—	—	—	1.481	1.666	1.851	2.037	2.222	2.407	2.592
50	157	—	—	—	—	—	1.539	1.732	1.924	2.117	2.309	2.501	2.694
51	160	—	—	—	—	—	1.598	1.798	1.998	2.197	2.397	2.597	2.797
52	163	—	—	—	—	—	1.658	1.866	2.072	2.280	2.487	2.695	2.902
53	166	—	—	—	—	—	1.723	1.938	2.153	2.369	2.584	2.799	3.014
54	170	—	—	—	—	—	1.784	2.007	2.230	2.453	2.675	2.900	3.123
55	173	—	—	—	—	—	1.851	2.082	2.314	2.545	2.777	3.008	3.239
56	176	—	—	—	—	—	1.915	2.154	2.394	2.634	2.873	3.112	3.351
57	179	—	—	—	—	—	1.980	2.228	2.475	2.723	2.970	3.218	3.465
58	182	—	—	—	—	—	2.050	2.307	2.563	2.819	3.075	3.331	3.588
59	185	—	—	—	—	—	2.117	2.382	2.646	2.911	3.175	3.440	3.705
60	188	—	—	—	—	—	2.190	2.463	2.737	3.010	3.284	3.558	3.832
61	192	—	—	—	—	—	—	2.540	2.823	3.105	3.388	3.670	3.952
62	195	—	—	—	—	—	—	2.619	2.910	3.205	3.492	3.784	4.074
63	198	—	—	—	—	—	—	2.704	3.005	3.305	3.606	3.907	4.207

APPENDIX 1 (*concluded*)

c) TARIFF TABLE DESIGNED IN CYPRUS FOR BLACK POPLARS (CYPRUS BLACK POPLAR)

(Volume in cubic meters)

Source: Forest Service of Cyprus

Height Feet		15	20	25	30	35	40	45	50	55	60	65	70	75	80
m.		4.65	6.20	7.75	9.30	10.4	12.4	14	15.5	17	18.5	20	21.5	23.2	24.75
Circumference Feet	cm.														
1.0	31	0.028	0.042	0.056	0.068	0.084	0.099	0.112							
1.5	46	0.047	0.064	0.088	0.112	0.134	0.154	0.176	0.211						
2.0	62	0.075	0.104	0.137	0.17	0.2	0.226	0.257	0.299	0.364	0.445				
2.5	77		0.154	0.212	0.260	0.308	0.34	0.379	0.431	0.515	0.588	0.652	0.730	0.814	0.879
3.0	93					0.442	0.478	0.519	0.574	0.644	0.736	0.817	0.896	0.980	1.066
3.5	104						0.616	0.663	0.739	0.795	0.896	0.980	1.089	1.181	1.290
4.0	124								0.935	0.966	1.089	1.164	1.285	1.397	1.526
4.5	140									1.125	1.265	1.377	1.484	1.624	1.764
5.0	155									1.318	1.458	1.573	1.705	1.853	1.996
5.5	170											1.792	1.946	2.080	2.248

APPENDIX 2

SOME DATA ON POPLAR GROWING IN THE NETHERLANDS
COST AND YIELD OF LINE PLANTATIONS OF POPLARS ALONG HIGHWAYS AND BETWEEN PLOTS OF CULTIVATED LAND

Data supplied by Prof. G. Houtzagers

Costs are calculated in man-hours (m.h.) per 100 trees. In the Netherlands the cost of one hour's work, including social charges, insurance, etc. amounts to about 1.60 florins.

1 Dutch florin (f.) = £ 0.094 = U.S. $0.26
Rate of interest. = 3 %
Rotation = 25 years
Yield of timber measured over bark to a minimum diameter of 16 cm. = 2 m³ per tree

Planting and replacements

1st year:	
Digging 100 planting pits (1.25 × 1.25 × 0.60 m.) for the planting	
75 m.h. = f. 120 brought forward at compound interest for 25 years at 3 % = 2.094 × 120	= f. 251
Purchase of 100 plants at f. 2.50 each including transport = f. 250 brought forward at compound interest for 25 years at 3 % = 2.094 × 250	= f. 523
Planting costs, 50 m.h. = f. 80 × 2.094	= f. 168
2nd year:	
Replacements 10 %	
10 % of the purchase price of the plants = f. 25 brought forward at compound interest for 24 years at 3 % = 25 × 2.033	= f. 51
	f. 993
± 15 % cost of digging pits and planting 20 m.h. = f. 32 × 2.033	= f. 65
Pruning (cost per hour = 1 m.h. + 50 % = f. 2.40)	
3rd year: 10 m.h. = f. 24 brought forward at compound interest for 23 years: 24 × 1.974	= f. 47
6th year: 15 m.h. = f. 36 brought forward at compound interest for 20 years: 36 × 1.806	= f. 65
9th year: 20 m.h. = f. 48 brought forward at compound interest for 17 years: 48 × 1.653	= f. 79
12th year: 25 m.h. = f. 60 brought forward at compound interest for 14 years: 60 × 1.513	= f. 91

15th year: 30 m.h. = f. 72
brought forward at compound interest for 11 years:
72 × 1.384 .... = f. 100
18th year: 35 m.h. = f. 84
brought forward at compound interest for 8 years:
84 × 1.267 .... = f. 106

Felling and extraction

92 trees (8 % loss on 100 trees)
5 m.h. per tree = 460 m.h. .... = f. 736

Management and supervision

f. 10 per year for 25 years = 36.46 × f. 10 .... = f. 365

Maintenance of roads and ditches

8 m.h. per year = f. 12.80
For 25 years = 36.46 × f. 12.80 .... = f. 467

Land tax and other taxes (if applicable)

f. 5 for 25 years = 36.46 × f. 5 .... = f. 182
f. 3 296

Timber yield in $\text{m}^3 = 92 \times 2 = 184\ \text{m}^3$

Net cost per m^3, excluding the soil rental $\frac{3\,296}{184} = \text{f. } 18$

or if the crop is sold as standing timber $\text{f.}18 - \frac{736}{184} = \text{f. } 14$

The soil rental has not been taken into account in this calculation. Taking the distance between trees to be 7 meters and assuming that the influence of a tree border extends over a strip 12 meters wide, the area affected by a row of 100 trees will be: 700 × 12 = 0.84 hectare, which corresponds to a soil rental at a value of f. 100 per hectare for 25 years of:

$$\frac{84}{100} \times 3 \times 36.46 = \text{f. } 92 \text{ or } \frac{92}{841} = \text{f. } 0.50 \text{ per m}^3 \text{ of wood}$$

A border planting on ground having a value of f. 2,500 per hectare would in this case represent a net cost of f. 18 + 25 × f. 0.50 = f. 30.50 per m^3 or f. 26.50 per m^3 if sold as standing timber.

It should be emphasized that the soil rental is always difficult to estimate, particularly for row plantings along highways and plots of land, since the soil is very often put simultaneously to other uses (agriculture, pasture, etc.). This factor has therefore been fixed at f. 100 per hectare, making it possible to examine each case in the light of local conditions.

If the timber yield is only 1.50 m^3 per tree after 25 years (on the poorest soils), the production cost will be:

$$\frac{3\,296 - 736}{138} = \text{f.}19 \text{ per m}^3 \text{ for standing timber}$$

$$\frac{3\,296}{138} = \text{f. } 24 \text{ per m}^3 \text{ for felled timber}$$

$$\text{plus f. } \frac{92}{138} = \text{f. } 67 \text{ for ground valued at f. } 100$$

APPENDIX 3

POPLAR CULTIVATION ON THE BANKS OF THE RIO GENIL

Data supplied by Messrs. José and Eduardo Rojas

The plantations studied are on alluvial soil and during their early years are combined with farm crops. The first year 20 tons of beet or 19 tons of potatoes are harvested per hectare. The second-year shade restricts cultivation to beans, which yield 3.8 tons per hectare.

Principles on which study is based

1. In view of the purpose of this study, 1 cubic meter of poplar wood has been taken as the unit measure for calculating the different production factors.

2. At the end of the rotation, the total revenue and total expenditure plus 5 percent interest were balanced.

3. Expenditure was made up of the following items:
   a) planting and cultivation costs brought forward at compound interest;
   b) annual soil rental brought forward at compound interest. The rental, including the cost of irrigation and maintenance, was estimated as 18.461 m^3.

4. Revenue was made up of the following items:
   a) income from first-year crops = 11.664 m^3, plus interest;
   b) income from second-year crops = 5.846 m^3, plus interest.

Method

There were two possible methods to be adopted:

i) analysis of total liabilities and assets at the end of the rotation; and
ii) analysis of each year's liabilities and assets.

By the first method the profit curve is analyzed, as it were, whereas the second method consists of analyzing the differential coefficient. In the first method, the ordinate represents the total revenue, while in the second the revenue is represented by the area between the axes, the curve and the ordinate. The second method has been chosen, since it enables the rotation giving the maximum yield to be determined.

Expenditure

Planting costs: let P = planting costs. P = 39.636 m^3 per hectare and includes the cost of working the soil, purchase of plants and fertilizers, and labor costs.

Therefore, for a given year n, the planting costs will be:

$$P \times (1 + t)^{n-2} \times t$$

Soil rental: let R = soil rental. The capital corresponding to the soil rental will be composed of accumulated annual rentals brought forward at compound interest, i.e. $\frac{R\ (1 + t)^{n-1} - 1}{t}$ and

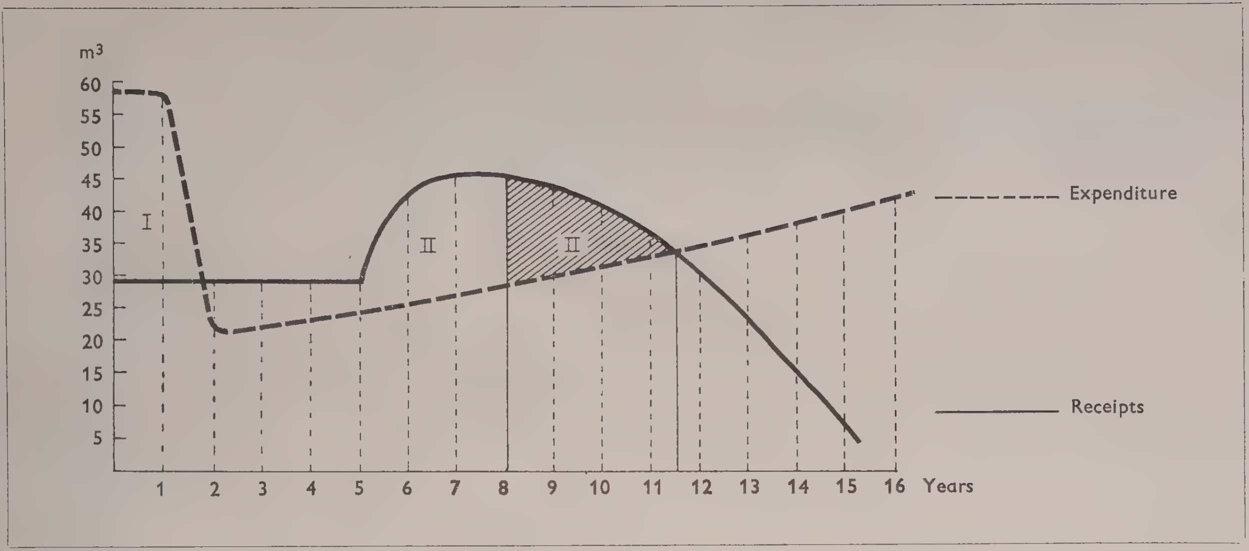
the expenditure for the year n will be the interest on this capital, i.e. $R\ (1 + t)^{n-1} - R$ to which will be added the annual rental, i.e.

$$R\ (1 + t)^{n-1}$$

Total expenditure for the year n will therefore be:

$$P\ (1 + t)^{n-2} \times t + R\ (1 + t)^{n-1}$$

CURVES OF ANNUAL RECEIPTS AND EXPENDITURE



Receipts

Value of the first-year crop = A. Receipts from this crop in the year n will consist of the interest on it, i.e., $A \times (1 + t)^{n-2} \times t$.

Value of the second-year crop = B. Receipts from this crop in the year n will be $B \times (1 + t)^{n-3} \times t$.

Value of the timber increment: this is the value of the annual increment. This value has been taken into account from the fifth year, after which the timber has a commercial value, i.e., C.

To conclude, receipts will therefore be:

$$A \times (1 + t)^{n-2} \times t + B \times (1 + t)^{n-3} \times t + C_n$$

The equivalent values for receipts and expenditure (expressed in cubic meters) are given in Tables 1 and 2:

TABLE 1. – VALUE OF RECEIPTS

Year	First term	Second term	Third term	Total
1	1.648	—	—	11.664
2	0.582	5.846	—	6.428
3	0.611	0.292	—	0.903
4	0.642	0.307	—	0.949
5	0.674	0.322	124.702	125.698
6	0.708	0.338	42.905	43.951
7	0.743	0.355	44.394	45.942
8	0.776	0.376	44.403	45.555
9	0.819	0.392	42.942	44.153
10	0.860	0.411	40.011	40.902
11	0.903	0.432	35.610	36.945
12	0.949	0.453	29.709	31.141
13	0.996	0.491	22.398	23.885
14	1.046	0.500	13.587	15.133
15	1.099	0.524	3.306	4.929
16	1.153	0.551	0.211	1.915

If receipts and expenditure are shown as two curves, the financial rotation is equivalent to the abscissa of the intersecting point of the two curves; that is, it occurs between 11 and 12 years, the profit being represented by the difference between areas II and I. It can be seen that the rotation which gives the maximum profit does not correspond to the actual rotation (8 years), since the owners in fact lose the receipts shown by the cross-hatched area.

TABLE 2. – VALUE OF EXPENDITURE

Year	First term	Second term	Total
1	39.636	18.461	58.096
2	1.982	19.384	21.366
3	2.081	20.362	22.443
4	2.186	21.378	23.564
5	2.295	22.448	24.743
6	2 410	23.556	25.966
7	2.529	24.737	27.266
8	2.656	25.974	28.630
9	2.788	27.267	30.055
10	2.927	28.633	31.560
11	3.058	30.073	33.131
12	3.229	31.568	34.797
13	3.389	33.156	36.545
14	3.578	34.817	38.375
15	3.738	36.552	40.290
16	3.924	38.380	42.304

The total profit is equal to the difference between the sum of annual receipts and the sum of annual expenditure:

Actual rotation (maximum increment) - 8 years

Receipts	281.074 m³	
Expenditure	232.074 m³	
Profit	49.000 m³	Annual profit: 6.125 m³

Financial rotation (corresponding to the maximum average increment over 11 years)

Receipts	403.074 m³	
Expenditure	326.820 m³	
Profit	76.254 m³	Annual profit: 6.932 m³

APPENDIX 4

POPLAR CULTIVATION IN THE AUBE REGION

Data supplied by Maître Chaton, Troyes

a) THEORETICAL YIELD OF POPLAR STANDS IN THE AUBE REGION

The following calculations have been made for *P. deltoides* cv. ' virginiana ' and should be reduced by – 10 to 20 percent for *P.* x *euramericana* cv. ' serotina de Champagne ' and – 20 to 30 percent for *P.* x *euramericana* cv. ' robusta '.

(U.S. $1 = 350 French francs)

Type of soil	Description of stand	Yield in m^3 and average price per m^3	1955 prices for standing timber (in Fr. fr.)	Utilization %
Exceptionally good, deep alluvial soil (very rare in the Aube; less than 1/10 of all stands)	25 years Spacing 9 × 9, i.e., 130 trees of which 110 survived, having an average circumference of 2 m. at 1.30 m. from ground, and are 25 m. high Volume: 110 × 4 = 440 m^3 Yield: 17.5 m^3 per ha. per annum	440 × 4 500	1 980 000	Choice veneer logs 25 Average veneer logs 30 1st quality timber 10 2nd quality timber 10 Package cases 25
Good deep soil (fairly rare in the Aube; 2/10 of all stands)	*a*) 25 years Spacing 8 × 8, i.e., 160 trees, of which 120 survived, having an average circumference of 1.70 m. at 1.30 m. from ground, and are 22 m. high Volume: 130 × 2.50 × 325 m^3 Yield: 13 m^3 per ha. per annum	325 × 4 000	1 300 000	Choice veneer logs 10 Average veneer logs 30 1st quality timber 15 2nd quality timber 15 Package cases 30

Type of soil	Description of stand	Yield in m^3 and average price per m^3	1955 prices for standing timber (in Fr. fr.)	Utilization %
	b) 20 years Spacing 8 × 8, i.e., 160 trees, of which 140 survived, having an average circumference of 1.50 m. at 1.30 m. from ground, and are 20 m. high Volume: 140 × 2 = 280 m^3 Yield: 14 m^3 per ha. per annum	280 × 3 500	840 000	Average veneer logs 25 1st quality timber 20 2nd quality timber 20 Package cases 35
Average quality not very deep soil (3/10 of all stands)	30 years Spacing 8 × 8, i.e., 160 trees, of which 130 survived, having an average circumference of 1.10 m. at 1.30 m. from the ground, and are 18 m. high Volume: 130 × 1 = 130 m^3 Yield: 4.3 m^3 per ha. per annum	130 × 2 500	325 000	1st quality timber 20 2nd quality timber 30 Package cases 50
Distinctly poor soil (4/10 of all stands)	Spacing 8 × 8, i.e., 160 trees of which 130 survived, having an average circumference of 0.80 m. at 1.30 m. from the ground, and are 15 m. high Volume: 130 × 0.50 = 65 m^3	65 × 2 000	130 000	Package cases 50 Firewood 50

APPENDIX 4

b) RENTABILITY OF POPLAR STANDS IN THE AUBE REGION*

(from exceptionally good and costly sites to poor and inexpensive sites)

Site quality	Establishment costs				Capital after felling		Ratio = capital after felling: initial capital
	Purchase price of land	Planting costs	Annual maintenance	Total	Value of land	Value of crop	
Exceptional	300 000	+ 60 000	+ 50 000	= 410 000	300 000	1 980 000 (440 m³)	=2 280/410 = 5.56
Very good	200 000	+ 60 000	+ 50 000	= 310 000	200 000	1 300 000 (325 m³)	=1 500/310 = 4.83
Fairly good	100 000	+ 60 000	+ 50 000	= 210 000	100 000	840 000 (280 m³)	= 940/210 = 4.47
Average	50 000	+ 60 000	+ 50 000	= 160 000	50 000	325 000 (130 m³)	= 375/160 = 2.34
Poor	25 000	+ 60 000	+ 50 000	= 135 000	25 000	130 000 (65 m³)	= 155/135 = 1.14

* Taxes are not included.

APPENDIX 5

ANALYSIS OF A BALANCE SHEET FOR THE EXPLOITATION OF A POPLAR STAND IN THE PO VALLEY

Summary of a report by V. Bellucci, published by E. Vaccarone

In the River Po Valley, alongside the river, is a property consisting of agricultural land and land reserved for poplar cultivation, the whole covering an area of 25.32 hectares and split into two portions 2 kilometers apart. One of the portions consists of a 12-year-old poplar stand covering a total area of 5 hectares which appear in the cadastral survey as two plots, details of which are given in Table 1. As regards the quality of the site, it may be said that the plot consists of 1 hectare of excellent land, 1.75 hectares of good land and 2.25 hectares of poor land, with a tree density per hectare of 340, 320, and 290 respectively. The highway is situated approximately 200 meters from the edge of the poplar plantation.

An estimate of the volume of timber extracted was carried out after felling by measuring selected tree types from the three classes of soil quality. It has thus been possible to assess the yield of timber, pulpwood and firewood per hectare for the three groups, as is shown in Tables 2 and 3. If the average specific weight of the green wood over bark is taken as 8 quintals per cubic meter, a total volume per hectare of 420, 294, and 168 cubic meters respectively is obtained for the three classes, giving an average annual increment of 35, 24.5 and 14 cubic meters per hectare. It should be noted that 30 percent of the timber from the highest fertility class can be used for plywood and only 5 percent from the poorest class.

The price of the standing timber for the different produce classes, calculated by the method shown in Table 4, has enabled the value of the total standing volume to be assessed (Table 5). It should be noted that timber and industrial wood account for 95 percent of the value of the standing timber (veneer logs 30 percent; pulp logs 17 percent; saw logs 47 percent; and firewood 6 percent) as against 83 percent of the quantity.

In order to assess the probable market value of the bare land immediately after the area has been utilized, the characteristics of the land regime and of the method of cultivation employed must be taken into account.

The land set aside for crops each year (15 hectares) is partly let out to peasants and partly cultivated by hired labor. The crops consist chiefly of forage crops for livestock, cereals and cash crops. The whole area can be irrigated if necessary. The woodland (9.50 hectares) is situated along the side of the river and is closely associated with the agricultural economy. The 5 hectares of forest in question are managed so that river water can be used for irrigating the crops grown between the lines of trees during the early years of the planting.

The poplars reach maturity after 12 years. Immediately after the area has been felled it is prepared for a new planting; the holes left by the extraction of mature trees are filled and new pits are prepared for the young poplars. These are 2-year-old nursery plants which are planted at a density of 360 to the hectare.

At the same time as the poplars are planted, a maize crop is sown between the rows. This is followed by a corn crop, then potatoes and maize, and lastly a forage crop. The latter is used for hay for four successive years; that is, from the fourth to the seventh year following the establishment of the poplars. After this, agriculture is limited to a little grazing, since the shade from the now adult poplars considerably limits the vegetation. The crops mentioned, which are grown under irrigation, are cultivated by hired labor. The aim is, on the one hand, to use the land for an auxiliary crop, and on the other to give the poplars the benefit of successive soil cultivation, both surface and deep, and of manuring. The poplars are pruned three times in all, in the fourth, seventh and tenth years, and in the eighth year the land is ploughed up again by tractor.

Table 6 shows the receipts and expenditure per hectare for each year of the rotation for the three separate classes of soil quality and for the whole 5 hectares. Receipts and expenditure for each year of the rotation were analyzed separately for the poplars and for the herbaceous crops grown between them during the early years of the stand. Such a distinction cannot, however, be complete since a large part of the manuring intended for the crops is of direct benefit to the poplars. Moreover, on the expenditure side, certain items of a special character in the over-all total were examined separately; these included, for example, maintenance of fixed assets (buildings, roads, etc.) organization and administration, and rates and taxes.

In Table 7, receipts and expenditure are balanced for each year of the rotation. These balances are then carried forward to the end of the rotation in order to obtain the periodic constant land revenue, differed, for capitalization. This land revenue amounts to 5,711,293 lire for the whole area and 1,142,258 lire for an average hectare. This periodic value yields a constant annuity of 67,884 lire per average hectare.

By adopting a rate of capitalization (for example, 6 percent) which takes into account the frequency of damage from floods, the regular or irregular management of the economy, and the more or less close association with farm crops, it is possible to determine the commercial value of the total area.

TABLE 1. – CADASTRAL DATA

Type of crop	Class	Area in hectares	Revenue	
			from land	from agriculture
			in lire	
Forest	I	2.75	1 994	135
Forest	II	2.25	1 181	222
Total		5.00	3 175	357

TABLE 2. – YIELD OF PRODUCE PER HECTARE

Produce	Unit	Soil quality					
		excellent	%	good	%	poor	%
Timber and pulpwood for paper	Cubic meters	350		245		140	
Timber and pulpwood for paper	Quintals	2 800	83	1 960	83	1 120	83
Firewood	”	560	17	392	17	224	17
Total yield	”	3 360	100	2 352	100	1 344	100

TABLE 3. – CLASSIFICATION OF THE PRODUCTION IN A 12-YEAR-OLD STAND

Class of product	Excellent soil			Good soil			Poor soil		
	quintals	%	%	quintals	%	%	quintals	%	%
Veneer logs	840	30		490	25		56	5	
Sawlogs	1 344	48		980	50		672	60	
Paper pulpwood	616	22		490	25		392	35	
Total: timber and industrial wood	2 800	100	83	1 960	100	83	1 120	100	83
Stumpage	272	49		176	45		87	39	
Firewood	124	22		90	23		52	23	
Faggots	164	29		126	32		85	38	
	560	100	17	392	100	17	224	100	17
Total: timber, industrial wood and firewood	3 360	100	100	2 352	100	100	1 344	100	100

TABLE 4 - PRICE OF STANDING TIMBER (in lire)

Class of product	Price of standing timber	Excellent soil		Good soil		Poor soil	
		yield per hectare	value of standing timber	yield per hectare	value of standing timber	yield per hectare	value of standing timber
Veneer logs	1 302.1	840	1 093 764	490	638 029	56	72 917
Paper pulpwood	593	616	365 288	490	290 570	392	232 456
Sawlogs	890.4	1 344	1 196 697	980	872 592	672	598 348
Total: lumber and paper logs		2 800	2 655 749	1 960	1 801 191	1 120	903 721
Faggots	215	2 050	5 125	1 575	3 937	1 060	2 650
Firewood	296.7	124	36 800	90	26 700	52	15 400
Stumpage	61.8	272	16 809	176	10 876	87	5 376
Total: firewood			58 734		41 513		23 426
General total:			2 714 483		1 842 704		927 147

Table 5. – Evaluation of standing timber (in lire)

Item	Veneer logs				Paper pulpwood				Sawlogs			
	Totals	%	Partial total	%	Totals	%	Partial total	%	Totals	%	Partial total	%
1. Selling price of 1 quintal of unbarked timber in the round loaded for transport	1 650.0	100			800.0	100			1 150.0	100		
2. Felling, trimming, crosscutting, loading for removal from the forest			170.0	49			120.0	58			140.0	54
3. Extraction and loading on lorry			39.0	11			18.0	9			22.0	9
4. Organization and supervision (10 % on items 2 and 3)			20.9	6			13.9	7			16.2	6
5. Interest charges and insurance (12 % of item 1 for 3 months)			49.5	14			24.0	11			34.5	13
6. Indirect costs, IGE, registration of contract (5 % on item 1 less 2, 3, 4, 5)			68.5	20			31.2	15			46.9	18
7. Total expense of timber conversion	347.9	21		100	207	26		100	259.6	23	100	100
8. Price of standing timber	1 302.1	79			593	74			890.4	77		

Table 5. – Evaluation of standing timber (in lire) (*continued*)

Item	Faggots [1]				Firewood				Stumpage			
	Totals	%	Partial total	%	Totals	%	Partial total	%	Totals	%	Partial total	%
1. Selling price per quintal (in place of freightage outside forest)	12.0	100			390.0	100			250.0	100		
2. Conversion			6.0	63			—	—			100.0	53
3. Removal and stacking on roadside			2.0	21			60.0	64			58.5	31
4. Organization and supervision (10 % on items 2 and 3)			0.8	9			6.0	6			16.0	8
5. Interest charges and insurance (12 % of item 1 for 3 months)			0.4	4			11.7	13			10.5	6
6. Indirect costs, IGE, registration of contract (5 % on item 1 less 2 + 3 + 4 + 5)			0.3	3			15.6	17			3.2	2
7. Total expense of timber conversion	9.5	79		100	93.3	24		100	188.2	75		100
8. Price of standing timber	2.5	21			296.7	76			61.8	25		

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[1] Figures relate to one faggot.

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
FIRST YEAR							
Receipts							
Maize (quintals)	40	32	24	5 000	200 000	160 000	120 000
Total receipts per hectare					200 000	160 000	120 000
Expenditure							
Filling in holes (number)	340	320	290	37	12 600	11 800	10 700
Marking out and digging fresh holes[1] (number)	360	360	360	20	7 200	7 200	7 200
Purchase of young poplars (number)	360	360	360	200	72 000	72 000	72 000
Transport of young poplars (number)	360	360	360	5	1 800	1 800	1 800
Planting young poplars (number)	360	360	360	20	7 200	7 200	7 200
Fertilizers (phosphates 5; nitrogen 1.5; potassic salts 1.5; quintals)					18 500	18 500	18 500
Cost of spreading fertilizers					2 000	2 000	2 000

[1] The holes were made with an auger operated by a 35 h. p. tractor.

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*continued*)

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
Ploughing					6 000	6 000	6 000
Harrowing					1 300	1 300	1 300
Maize seed (quintals)	0.5	0.5	0.5	5 000	2 500	2 500	2 500
Sowing the maize seed and rolling					7 500	7 500	7 500
Weeding of maize					10 000	10 000	10 000
Ridging of maize					5 800	5 800	5 800
Maize crop (quintals)	40	32	24	400	16 000	12 800	9 600
Stripping leaves and threshing of maize (quintals)	40	32	24	300	12 000	9 600	7 200
Drying and storage of maize (quintals)	40	32	24	60	2 400	1 900	1 400
Irrigation					8 000	8 000	8 000
Interest on loans (6 % for 4 months)					3 800	3 700	3 600
Administration and supervision					5 000	5 000	5 000
Upkeep of fixed assets (buildings, roads)					4 000	4 000	4 000
Rates and taxes					8 500	8 500	7 600
Total expenditure per hectare					214 100	207 100	198 900

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*continued*)

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
SECOND YEAR							
Receipts							
Corn (quintals)	30	25	20	6 800	204 000	170 000	136 000
Straw (quintals)	35	25	22	1 000	35 000	25 000	22 000
Total receipts per hectare					239 000	195 000	158 000
Expenditure							
Replacement of failures (number)	18	29	54	245	4 400	7 100	13 200
Ploughing of stubble					3 000	3 000	3 000
Ploughing by tractor and cultivation between poplar rows					7 000	7 000	7 000
Harrowing					1 300	1 300	1 300
Fertilizers (phosphates 5; nitrogen 1.5; potassic salts 1.5; quintals)					18 500	18 500	18 500
Cost of spreading fertilizers					2 000	2 000	2 000
Corn seed (quintals)	2.1	2.1	2.1	9 000	18 900	18 900	18 900
Sowing and rolling					3 000	3 000	3 000

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*continued*)

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
Weeding and cleaning					2 000	2 000	2 000
Nitrates, and spreading of fertilizers (quintals)	2.0	2.0	2.0	4 500	9 000	9 000	9 000
Corn crop					13 000	12 100	11 000
Transport to the farm					10 000	10 000	8 600
Threshing					18 000	16 000	14 000
Storing					1 800	1 500	1 200
Ploughing of stubble					1 500	1 500	1 500
Irrigation					8 000	8 000	8 000
Anti-worm treatment					2 000	2 000	2 000
Interest on loans (6 % for 4 months)					2 500	2 500	2 500
Administration and supervision					5 000	5 000	5 000
Upkeep of fixed assets (buildings, roads)					4 000	4 000	4 000
Rates and taxes					8 500	8 500	8 500
Total expenditure per hectare					143 400	142 900	144 200

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*continued*)

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
THIRD YEAR							
Receipts							
1. Vetch oats, green forage (quintals)	400	300	250	220	88 000	66 000	55 000
2. Maize and *Vigna sinensis* (green forage) (quintals)	500	400	300	200	100 000	80 000	60 000
Total receipts per hectare					188 000	146 000	115 000
Expenditure							
Organic manure (quintals)	200	200	200	250	50 000	50 000	50 000
Ploughing by tractor					6 000	6 000	6 000
Chemical fertilizers (phosphates 4; nitrogen salts 1; quintals)					13 100	13 100	13 100
Loading, transport and and spreading of fertilizers and manure					10 200	10 200	10 200
Seeds (vetch 1.5; oats 1.5; quintals)					13 500	13 500	13 500
Sowing					1 000	1 000	1 000
Rolling					1 000	1 000	1 000

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*continued*)

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
Reaping					6 000	5 500	5 000
Transport and silage preparation					8 000	7 500	7 000
Cultivation					3 000	3 000	3 000
Ammonium sulphate					5 900	5 900	5 900
Spreading sulphate					600	600	600
Maize and *Vigna sinensis* seeds					22 500	22 500	22 500
Sowing					1 000	1 000	1 000
Rolling					1 000	1 000	1 000
Reaping					11 000	10 000	9 000
Transport and silage preparation					9 000	8 500	8 000
Second dressing (of the land)					1 500	1 500	1 500
Irrigation					8 000	8 000	8 000
Interest on loans (6 % for 4 months)					3 500	3 400	3 300
Administration and supervision					5 000	5 000	5 000
Upkeep of fixed assets					4 000	4 000	4 000
Rates and taxes					8 500	8 500	8 500
Total expenditure per hectare					193 300	190 700	188 100

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*continued*)

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
FOURTH YEAR							
Receipts							
Hay (quintals)	60	55	55	2 000	120 000	110 000	100 000
Total receipts per hectare					120 000	110 000	100 000
Expenditure							
Organic manure (quintals)	100	100	100	250	25 000	25 000	25 000
Chemical fertilizers (phosphates 4; potassium salts 1; quintals)					9 200	9 200	9 200
Loading, transport and spreading fertilizers and manure					7 000	7 000	7 000
Ploughing by tractor					6 000	6 000	6 000
Harrowing					1 300	1 300	1 300

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*continued*)

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
Seeds (clover 25; Italian ryegrass 15 kg.)					18 700	18 700	18 700
Rolling					1 000	1 000	1 000
Reaping					12 000	12 000	12 000
Haymaking and transport to barn					22 000	20 000	18 000
Anti-worm treatment					2 000	2 000	2 000
Irrigation					8 000	8 000	8 000
Interest on loans (6 % for 4 months)					2 100	2 000	2 000
Administration and supervision					5 000	5 000	5 000
Upkeep of fixed assets					4 000	4 000	4 000
Rates and taxes					8 500	8 500	8 500
Total expenditure per hectare					131 800	129 700	127 700

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*continued*)

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	Excellent	good	poor		excellent	good	poor
FIFTH YEAR							
Receipts							
Hay	30	20	17	1 800	54 000	36 000	31 000
Total receipts per hectare					54 000	36 000	31 000
Expenditure							
Anti-worm treatment					2 000	2 000	2 000
Pruning					9 000	9 000	9 000
Reaping					6 000	6 000	6 000
Haymaking and transport and storing in barn					12 000	11 000	10 000
Cultivation					3 000	3 000	3 000
Irrigation					8 000	8 000	8 000
Interest on loans (6 % for 4 months)					800	800	800
Administration and supervision					5 000	5 000	5 000
Upkeep of fixed assets					4 000	4 000	4 000
Rates and taxes					8 500	8 500	8 500
Total expenditure per hectare					58 300	57 300	56 300

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*continued*)

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
SIXTH YEAR							
Receipts					—	—	—
Expenditure							
Anti-worm treatment					2 000	2 000	2 000
Cultivation					3 000	3 000	3 000
Irrigation					8 000	8 000	8 000
Interest on loans (6 % for 4 months)					300	300	300
Administration and supervision					5 000	5 000	5 000
Upkeep of fixed assets					4 000	4 000	4 000
Rates and taxes					8 500	8 500	8 500
Total expenditure per hectare					30 800	30 800	30 800

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*continued*)

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
SEVENTH YEAR							
Receipts				—	—	—	—
Expenditure							
Pruning					11 000	11 000	11 000
Anti-worm treatment					2 000	2 000	2 000
Cultivation					3 000	3 000	3 000
Irrigation					8 000	8 000	8 000
Interest on loans (6 % for 4 months)					500	500	500
Administration and supervision					5 000	5 000	5 000
Upkeep of fixed assets					4 000	4 000	4 000
Rates and taxes					8 500	8 500	8 500
Total expenditure per hectare					42 000	42 000	42 000

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*continued*)

Year and operation	Per hectare of land			Price (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
EIGHTH - ELEVENTH YEARS							
Receipts					—	—	—
Expenditure							
Anti-worm treatment					2 000	2 000	2 000
Cultivation					3 000	3 000	3 000
Irrigation					8 000	8 000	8 000
Interest on loans (6 % for 4 months)					300	300	300
Administration and supervision					5 000	5 000	5 000
Upkeep of fixed assets					4 000	4 000	4 000
Rates and taxes					8 500	8 500	8 500
Total expenditure per hectare					30 800	30 800	30 800

TABLE 6. – ANNUAL EXPENDITURE AND RECEIPTS (*concluded*)

Year and operation	Per hectare of land			Price [1] (in lire)	Value in lire per hectare of land		
	excellent	good	poor		excellent	good	poor
TWELFTH YEAR							
Receipts							
Veneer logs	840	490	56	1 302.1	1 093 764	638 029	72 918
Sawlogs (quintals)	1 344	980	672	890.4	1 196 698	872 592	598 349
Paper pulpwood	616	490	392	593.0	365 288	290 570	232 456
Faggots	2 050	1 575	1 060	2.5	5 125	3 937	2 650
Firewood (quintals)	124	90	52	2 967.0	36 791	26 703	15 428
Stumpage (quintals)	272	176	87	61.8	16 810	10 877	5 377
Total receipts					2 714 476	1 842 708	927 168
Expenditure							
Irrigation					8 000	8 000	8 000
Administration and supervision					5 000	5 000	5 000
Upkeep of fiwed assets					4 000	4 000	4 000
Rates and taxes					8 500	8 500	8 500
Total expenditure per hectare					25 500	25 500	25 500

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[1] Prices refer to standing timber.

TABLE 7. – ANNUAL BALANCE OF EXPENDITURE AND RECEIPTS PER HECTARE

Year of rotation	Excellent land				Good land				Poor land			
	Balance of receipts and expenditures for each year of the rotation		Annual balances carried forward to end of rotation		Balance of receipts and expenditures for each year of rotation		Annual balances carried forward to end of rotation		Balance of receipts and expenditures for each year of rotation		Annual balances carried forward to end of rotation	
	positive values	negative values	positive values	negative values	positive values	negative values	positive values	negative values	negative values	positive values	negative values	positive values
1		14 100		26 766		47 100		89 410		78 900		189 830
2	85 000		153 296		53 100		95 094		13 800		24 714	
3		5 300		8 954		44 700		75 520		73 100		123 500
4		11 800		18 807		19 700		31 398		27 700		44 150
5		4 300		6 465		21 300		32 027		25 300		38 042
6		30 800		43 690		30 800		43 690		30 800		43 690
7		42 000		56 205		42 000		56 205		42 000		56 205
8		30 800		38 885		30 800		38 885		30 800		38 885
9		30 800		36 683		30 800		36 683		30 800		36 683
10		30 800		34 607		30 800		34 607		30 800		34 607
11		30 800		32 648		30 800		32 648		30 800		32 648
12	2 688 984		2 688 984		1 817 208		1 817 208		902 668		902 668	
			2 842 280	303 700			1 912 298	471 073			927 382	638 240
	Constant differed land revenue per hectare: 2,538,580 lire. This periodic value corresponds to a constant annuity of 150,487 lire.				Constant differed land revenue per hectare: 1,441,225 lire. This periodic value corresponds to a constant annuity of 85,436 lire.				Constant differed land revenue per hectare: 289,142 lire. This periodic value corresponds to a constant annuity of 17,520 lire.			

NOTE: Constant differed land revenue for the whole area: 5,711,293 lire, i.e. per average hectare – 1,142,258 lire. These periodic values correspond to constant annuities of 339,420 lire for the whole area and 67,884 lire per average hectare.

III. POPLAR GROWING IN THE FOREST

Although poplars are not true forest species (with the exception of aspens), they will nevertheless be called upon to play an important role in the forests of the future, particularly broadleaved forests.

The genus *Populus* grows in the natural state in the Northern Hemisphere, chiefly between the 30th and 60th parallels, where its representatives occur both in pure stands and in mixture with other species.

It is very difficult to estimate the area of these natural stands; in fact, information is either lacking altogether or is very unreliable. The results of estimates are further falsified by the fact that poplars are often grown outside their natural distribution area, and the amazing facility with which some types multiply, either by seeds or root suckers, often gives the impression that certain stands are natural when in fact they are not. It is also recognized that poplars growing in nature were far more widely distributed in the past than they are today. They have been banished from many places to make room for agriculture, which is more profitable. Land clearing, which has wiped out forests containing a large proportion of poplars, and drainage, which has lowered the level of the water table, have both helped to speed up their elimination. Population increases, the spread of towns and villages and the ever-growing needs of municipal and rural economies have led to the deforestation of large areas which were partly occupied by poplars. In addition, the study and cultivation of the genus has been neglected for too long. Hence poplars, although capable of a high timber yield in a very short time, have disappeared from the forest. It should be added that their wood was, for a long time, considered as a second-rate softwood.

Excessive logging, lack of understanding of poplar needs and lack of treatment have contributed to the absence of poplars from many forests. For several years now there has been a trend toward the restocking of derelict stands by the introduction of poplars wherever they are capable of improving the standing timber.

Before setting out the reasons for growing poplars in the forest, and the most efficient methods of cultivation, it seems expedient to see how they behave in nature and what care should be given them. Later, the cultivation of poplars in the forest will be discussed, differentiating between alluvial and nonalluvial forests.

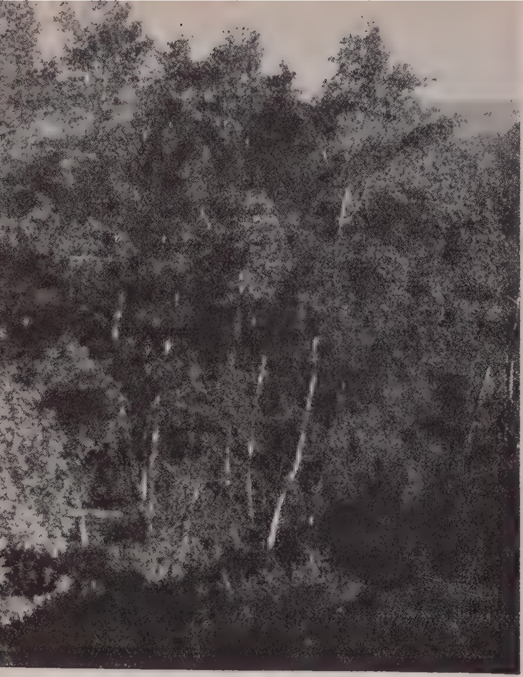


FIGURE 92. – Natural stand of *P. alba* var. *subintegerrima* at Tahanaout, near Marrakesh, Morocco.

Courtesy *R. Rol*

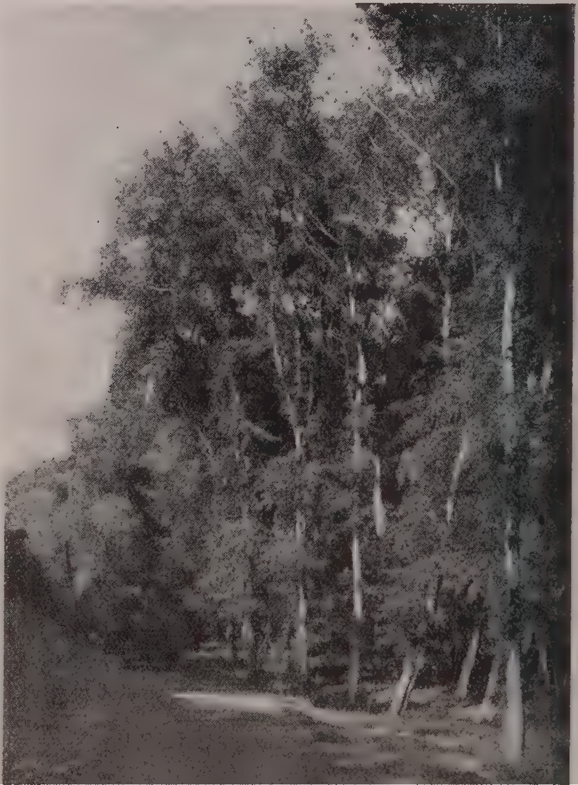


FIGURE 93. – Natural stand of *P. alba* var. *hickeliana* in the Korifla gorges, Morocco.

Courtesy *R. Rol*

FIGURE 94. – Aspen growing at an altitude of 1,850 meters above Bonneval-sur-Arc-en Maurienne, Haute-Savoie, France.

Courtesy *Marcet*

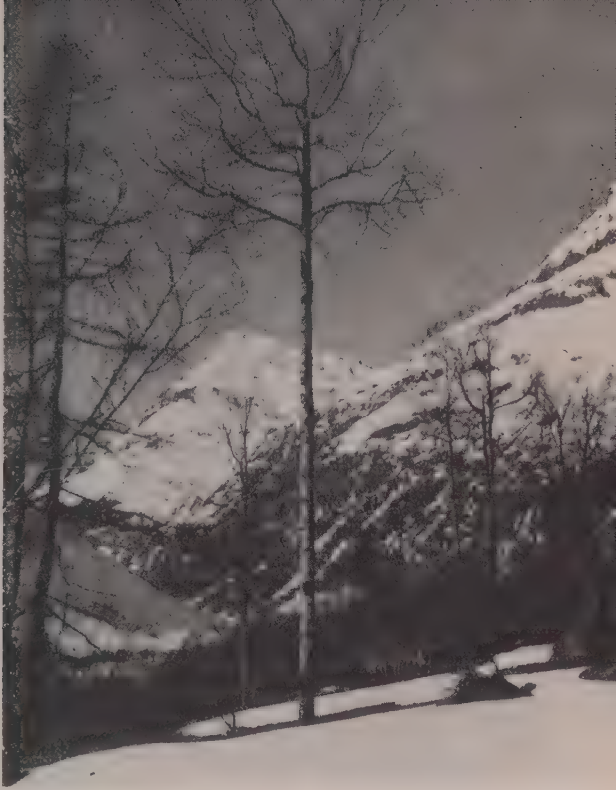
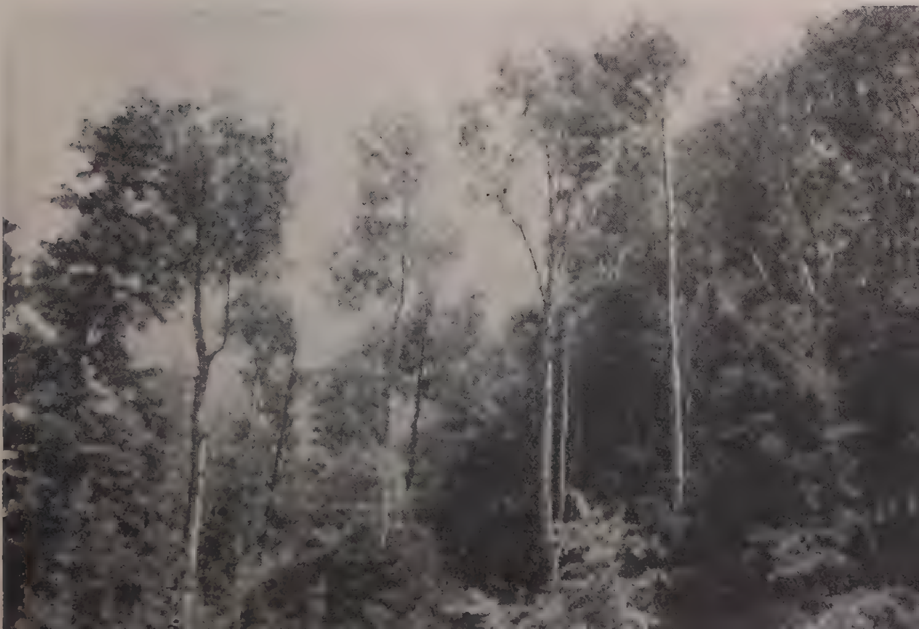


FIGURE 95. – *P.* x *canescens* growing in mixture with fir in the Sila Piccola, Calabria, Italy.

Courtesy *G. Giordano*



A. NATURAL STANDS AND THEIR TREATMENT

Poplars of all sections are to be found growing in natural stands. *Leuce* poplars, that is, white poplars and aspens, have a very extensive habitat. It can be claimed that they tolerate the continental climate of the pre-Asian steppes as well as the oceanic climate of Ireland, the torrid heat of the Moroccan plains or the severe winters of Leningrad. With their extensive distribution both as regards altitude and latitude, they are found associated with a variety of species in widely varying regions, on plain and mountain alike.

It may be recalled briefly that *Populus alba* L. is a tree of the Mediterranean basin and the Near East and that *Populus tremula* L. has a distribution which extends in a north-south direction from Lapland to the Mediterranean basin, and in a west-east direction from Portugal and Ireland to eastern Asia; and between white poplar and aspen there are innumerable spontaneous hybrids, of which *P. canescens* is one.

Poplars of the *Aigeiros* group are represented in nature by *Populus nigra* L. and *Populus deltoides* Marsh., the former being the black poplars of the Old World and the latter the black poplars of the east of North America.

Populus euphratica Oliv. (*Turanga* section) constitutes natural stands which are of interest only in the Near and Middle East.

Poplars of the *Tacamahaca* group are of importance in North America and the Far East and similarly *Leucoides* poplars, which are, however, only of minor importance.

COMPOSITION OF NATURAL STANDS

Section *Leuce*

Subsection *Albidae*, type *P. alba*

White poplars grow in abundance on recent alluvial deposits of large and small rivers. They are localized chiefly in southern Europe, where they find the soil and climate which favor them. They need more heat than black poplars and consequently do not grow so high up the river courses which flow down from the Alps. It is, however, a fact that *Populus* *alba* grows naturally up to a height of 1,150 meters in the Valais (Switzerland); but in these cases, there are only isolated trees and no stands. White poplars are, therefore, a heat-demanding and moisture-demanding species. The fact that they are not found growing naturally in cold regions, whereas if planted there they hold their own fairly well, may be accounted for by the rapid fall off of germination in cold zones, which thus prevents natural seeding. White poplars are more exacting in their site requirements than aspens because their root system penetrates deeper.

They are represented in innumerable plantations: throughout the Iberian Peninsula; in France — in the basin of the River Garonne and of the lower Rhône; in southern Germany; in Austria — on the banks of the Danube, in the Tyrol and the Vorarlberg; in Switzerland; Hungary (Puszta); Yugoslavia; Bulgaria; U.S.S.R.; Mongolia; Afghanistan; Pakistan; Tibet and French North Africa. Undoubtedly their favorite habitat is along river banks where the soil is fresh, deep and rich in humus. On banks of recent sand deposits, *Polygonum*, *Chenopodium* and *Myricaria* take root in succession and in between them spring up willows and poplars (*P. alba* and *P. nigra*). This pioneer vegetation is strongly invaded by shrubs and grasses but the willows, alder and poplars gradually constitute a thicket in which the undergrowth disappears due to lack of light. Where the humus is not carried away by floods but on the contrary is enriched by deposits of silt, a typical mixed forest arises where willows and alder lose ground and are finally dominated by the poplars.

Although *P.* x *canescens* is a hybrid of *P. alba* and *P. tremula*, it deserves to be mentioned separately because of its importance in certain countries. It is found in the south of Great Britain and Ireland, on the inland dunes of the Netherlands, on the Scandinavian Islands of Sylt and Föhr, in Germany, Austria, France, Italy (in Calabria and other districts), Switzerland, Yugoslavia, etc.

P. x *canescens* is content with shallow and sandy soils or, on the contrary, compact soils.

Subsection *Trepidae*

Natural populations of aspen are better known than the former and are distributed throughout practically the whole of Europe, part of Asia, in the northeast and west of the United States of America, in Canada, China and Japan. They are the only poplars which can be considered true forest species, and are found on plains and mountains alike, depending on the variety. They are not affected by the geological nature of the soil and in mountain regions show preference for gentle slopes rather than hollows where they are exposed to spring frosts. On flat ground they are less exacting and are sometimes content with a compact, poor quality soil. They grow in very different types of forest, and are as likely to be found in pure stands on wooded pastures and sites which have been burned or clear-felled, as they are in mixture with a wide variety of broadleaved species. They mix well with beech, *Pinus sylvestris*, spruce and other species. For example, in the virgin forest of Perucica in Bosnia in a beech-pine plantation at a height of 1,150 meters, 60-year-old aspens attain a diameter of 70 centimeters and a height of 60 meters.

In the Alps, very fine specimens thrive up to a height of 1,800 meters in the subalpine spruce forests of *Picea excelsa* and in the forests of arolla pine (*Pinus cembra*) and larch.

Whereas in Eurasia only *P. tremula* is really well known under the name of aspen, the Americans have given this name to two different species: *Populus tremuloides* Michx. (quaking aspen) and *Populus grandidentata* Michx. (big-tooth aspen). *P. tremuloides* is the equivalent of *P. tremula* and the two form the limit of arboreal vegetation around the pole. The former has, therefore, a much more extensive distribution than that of *P. grandidentata*, which is found chiefly in the Lake States and in the northeast of North America.

The importance of natural stands of aspen varies very considerably in Europe. Poplars become increasingly frequent as one moves to the north and east and they constitute extensive forests in Finland and Sweden, where the volume of standing timber is as much as 40 million cubic meters, yielding 2 million cubic meters annually. In Finland, aspens hold fourth place in the order of importance of forest species. They are abundant in the U.S.S.R., and in France they are represented by trees having a fine habit in the high regions of the Alps and in some valleys of the Pyrenees. They occupy innumerable sites in groups of varying size in Great Britain, Germany, Yugoslavia, Italy (Aspromonte, the Province of Vercelli and the valleys of the western Alps), Switzerland and in many other parts of Europe which cannot be enumerated here. Aspens also appear to occur naturally in the Near East.

They hold a place of primary importance in America where around the Great Lakes alone they occupy approximately 40 percent of the utilizable forest area. The total standing timber in the U.S.A. exceeds 110 million cubic meters, of which one tenth is composed of sawlogs and the rest of pulpwood. Annual production at present amounts to about 720,000 cubic meters, of which at least two thirds comes from the Lake States and the northeast.

Section *Aigeiros*, types *P. nigra* L. and *P. deltoides* Marsh.

P. nigra L.

Natural stands of black poplar have a distribution which quite often overlaps that of the white poplars and sometimes that of the aspens.

European black poplars are to be found throughout western, southern and central Europe and are known as the old European black poplars. They occupy the sandy banks and wastelands of rivers and torrents up to a fairly high altitude, and grow as individuals in mixture with willow, birch and alder. They remain in this association so long as alluvial deposits do not change the soil conditions, and other species, such as ash and oak, do not establish themselves.

Populus nigra also occurs naturally in Turkey, Libya and North Africa.

P. deltoides Marsh.

In America these poplars, known as "cottonwoods," are found growing naturally from the Atlantic to the Great Plains and from the Great Lakes to the Gulf of Mexico. Along the great rivers such as the Mississippi, the Ohio and the Missouri, they form true forests where purely natural regeneration takes place. Poplars occupy the "bottomlands" or alluvial ground and the more marshy areas known as "swamplands."

Poplars are associated in the forests of the United States with a wide range of other species, such as *Nyssa aquatica*, L., *Nyssa sylvatica* Marsh., *Liquidambar styraciflua* L., bald cypress, ash, oak, pine, elm, willow, *Acer rubrum* L. etc., according to the soil evolution.

The "bottomland" forests consist of:

a) *Cottonwood-willow forests* or forests composed chiefly of poplars and willows: and
b) *Swampland forests or cypress-tupelo types*, whose chief characteristic is the presence of bald cypresses (*Taxodium distichum* L.) and *Nyssa aquatica* L.

Natural stands of black poplar are thus composed of a certain number of genotypes which have grown up in dense stands and which have undergone a process of natural selection.

Similar stands are also to be met with in southeast Canada, in the south of Ontario as far as Ottawa, and all along the St. Lawrence River. However, the trees are not such fine specimens as those which grow on

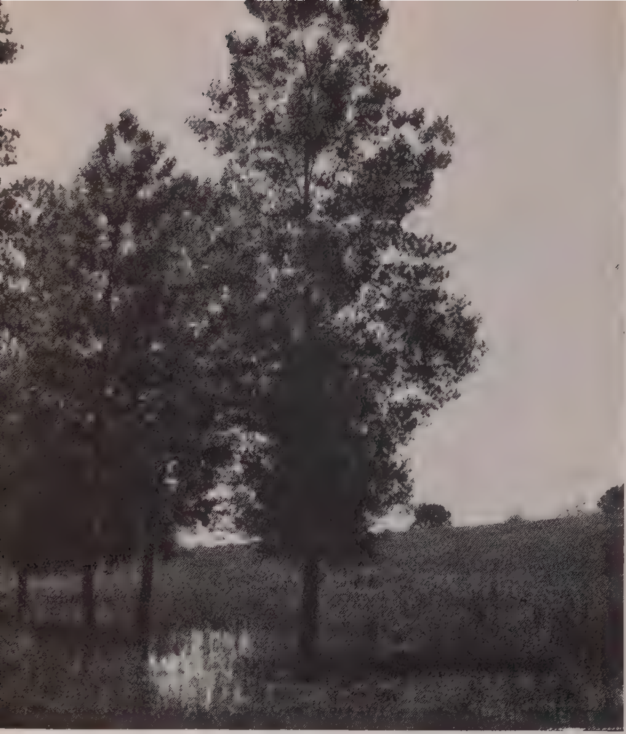


FIGURE 96. – *P. deltoides missouriensis* at Murphysboro, Illinois, U.S.A.

Courtesy *R. Rol*

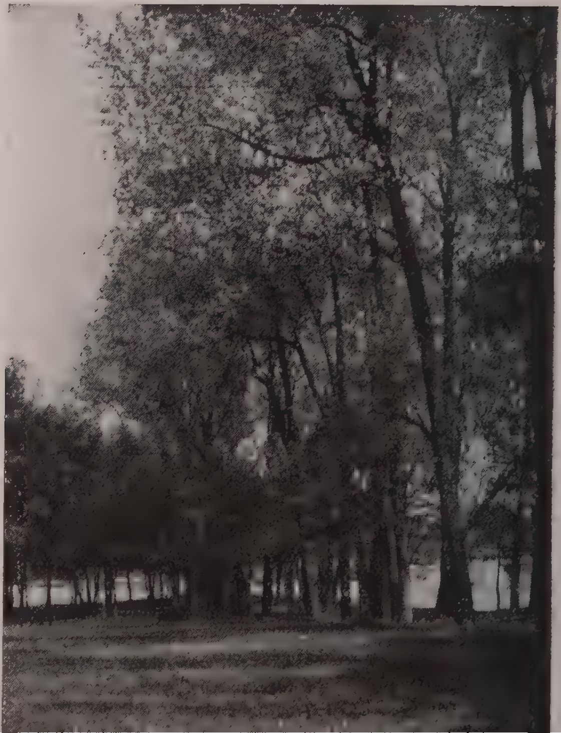


FIGURE 97. – *P. deltoides monilifera* in the Titabawa River Valley, Emerson Park, Midland, Michigan, U.S.A.

Courtesy *R. Rol*

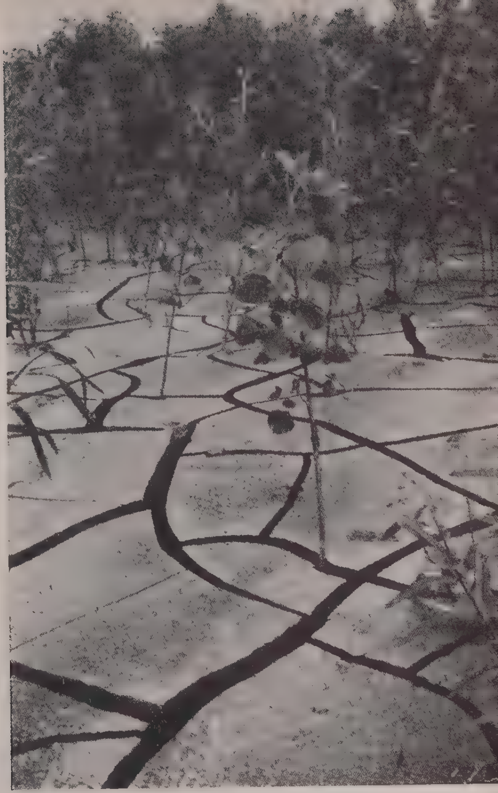


Figure 98. – Seedlings of *P. deltoides* and *Salix* on the banks of the Mississippi, U.S.A.

Courtesy *R. Rol*

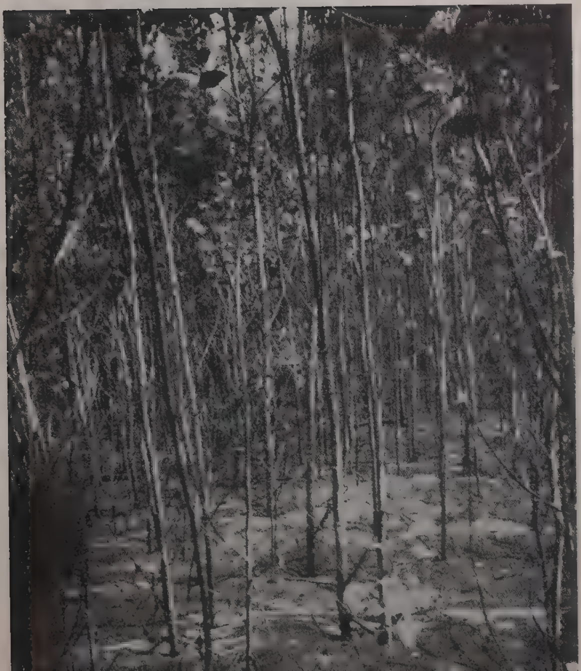


Figure 99.–4-year-old willows and poplars at Vicksburg, Mississippi, U.S.A.

Courtesy *R. Rol*

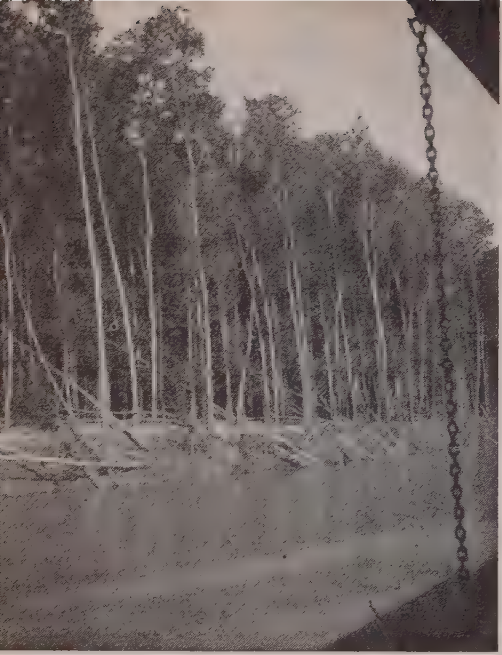


FIGURE 100. – 12-to-15-year-old *P. deltoides* on the banks of the Mississippi at Vicksburg, Mississippi, U.S.A.

Courtesy *R. Rol*

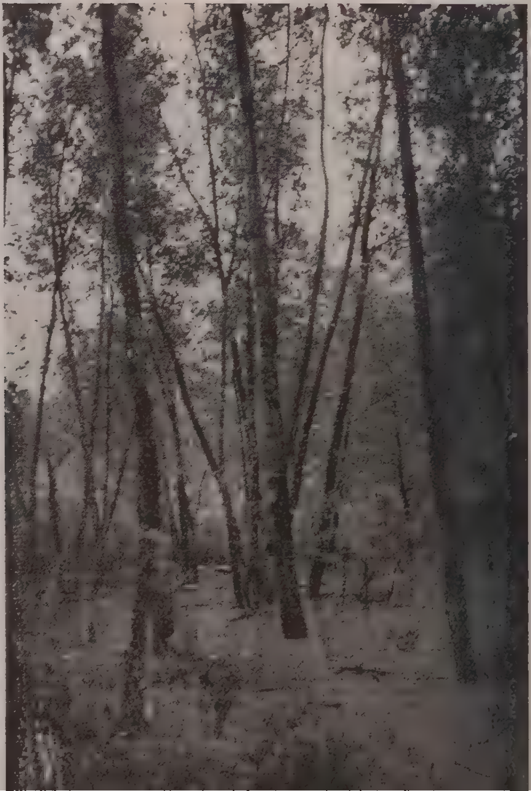


FIGURE 101. – 20-year-old stand of *P. deltoides* at Cairo, Mississippi, U.S.A.

Courtesy *R. Rol*

the banks of the Mississippi. Toward the northern limit of its distribution, *P. deltoides* is often found in mixture with *P. tacamahaca*, which is tolerant of a wider range of sites and can even attain large dimensions in acid, sandy or clay soils.

Section *Turanga*, type *P. euphratica* Oliv.

Natural stands of *P. euphratica*, as far as one can judge, have an immense distribution which stretches from the south coast of Spain to southern Turkestan and Afghanistan, passing through North Africa and Asia Minor. It is even found in India and Siberia (Altai Mountains).

In Iraq this species is generally called "gharab," but is also known by the name of "palk" in mountain regions and "safsaf" (Arab for "willow") in the valleys. It is found at altitudes ranging from sea level to 2,000 meters. The most extensive stands are situated in the wide, warm, sunny valleys where there is no fear of late frosts. During the growing season *P. euphratica* requires much light and heat. On the other hand, it tolerates a continental climate and dry soil, provided that the soil is well nourished, even with brackish water. In former times more than today *P. euphratica* constituted dense forests in mixture with willow, tamarisk and mulberry along all watercourses and their tributaries. These forests have been almost completely destroyed to supply firewood. A few have been spared along the Tigris and Euphrates Rivers on sites which were difficult of access, far from inhabited areas and periodically flooded by rivers in flood.

According to the director of forests for Syria, there are probably no virgin stands of *P. euphratica* left in the country. The finest specimens were felled long ago, and the quality of the trees which now occupy the banks of the Euphrates leaves much to be desired. In the absence of more detailed information, a cautious estimate of the area covered by natural stands of *P. euphratica* in Syria is about 3,000 hectares.

This species is also found growing naturally in ecologically similar conditions in southern Iran, between Bendar Abbas and Kerman, in Khuzistan in the valley of the Sefid Roud (Guilan), of the Gavarou (Kurdistan), in Lorestan and Kermanshah, in southeast Turkey, Israel and Egypt, between Mersa Matruh and the Siwa Oasis, and at Elbauseili near Rosetta, where it is known by the local name of "gharb." In Pakistan, stands with an understory of *Tamarisk* and *Saccharum* yield marketable timber at less than 25 years (diameter 25 to 30 centimeters, height 18 meters).

Section *Tacamahaca* (balsams)

These poplars are of importance in the Far East and in North America. Some types form dense stands along rivers, around lakes and on marshlands. They occur in natural association with willow, alder and birch and even with conifers. In the eastern U.S.A., *P. tacamahaca* constitutes stands with standing timber estimated at more than 2 million cubic meters, and having an annual yield of 90,000 cubic meters. In the west. stands of *Populus trichocarpa* have an estimated standing timber of more than 3 million cubic meters of logs for sawing and veneering.

This very brief indication of the location of natural poplar stands is followed by a description of the way in which poplars grow in natural stands, the importance attributed to them and how they should be treated.

STAND CHARACTERISTICS

It should be borne in mind that the poplar is not a climax species but a transitional species which, in order to survive, requires a very high degree of light and a soil sufficiently fresh. During the growing season in particular, when the temperature rises and precipitation is low, the freshness of the soil must compensate for the lack of water. This is the reason why the majority of natural stands are confined to the banks of rivers and torrents or to ground which, during the summer, has a subterranean water table within reach of the roots. If by chance the water table falls, the poplar is bound to die. On the other hand, excessive moisture over a long period, particularly stagnant water, is harmful to poplars and there is the risk of asphyxiating the roots. The amount of sunlight also appears to play an important part. It would be impossible otherwise to explain the presence of magnificent specimens on the Island of Capri, which is claimed to be the sunniest in the world and at the same time one of the driest.

In untended natural stands poplar regenerates with difficulty, and the stand becomes increasingly open as this species becomes more rare and finally disappears. In fact, one cannot conceive of poplar as a dominated species, or even as a codominant; it must predominate and be free of all competition. Aspens, however, which in some respects adapt themselves fairly well to the forest (this is particularly true in Finland where they grow over an area of some 40,000 hectares in mixture with conifers and birch), nevertheless seek sites which are freely exposed to the sun's rays, such as clear-felled and burned areas, open stands, and borders rather than the interior of stands.

In America, the aspens constitute immense stands on burned areas and are known as "temporary forest type;" that is to say, they form a first phase which, on the best soils, is followed by *Acer saccharum* Marsh., *Betula lutea* Michx., *Fagus grandifolia* Ehrh., *Tilia americana* L., *Ulmus americana* L.; and on poor soils by *Pinus resinosa* Ait., *Pinus strobus* L., *Pinus banksiana* Lamb., *Abies balsamea* Mill., *Tsuga canadensis* Carr. Regeneration is by suckering. It appears nevertheless that natural seeding can produce dense stands where growing conditions are favorable, such as in the region of the Great Lakes.

New alluvial soils deposited along the banks of the Mississippi are at once occupied by black poplars and willows (*Salix nigra* Marsh. and slick bark willow [*Salix longifolia* Mühlen]), which are first-rate pioneer species.

The poplars (chiefly *P. deltoides*) may appear at the same time as the willows or after them. If the proportion of willow is such that they form a dense cover, the poplars do not become established. *Salix longifolia* gradually disappears, while *Salix nigra*, which is more resistant, survives — often dominated by the poplars — or disappears in its turn in the course of the first fellings. With the growth of the stand the progressive rise in the ground level brings about a change in the water table, which permits the invasion of other broadleaved species. The following species then establish themselves in succession: *Platanus occidentalis* L., *Diospyros virginiana* L., *Carya pecan* Marsh., perhaps followed by *Quercus phellos* L., *Quercus nigra* L., *Quercus nuttalii* Palmer, *Quercus lyrata* Walt, etc., arriving at a climax association of, for example, *Quercus phellos — Liquidambar — Acer*.

Hence, there are some stands where poplars are found alone and others where they are associated with willows or other broadleaved species.

THE IMPORTANCE AND CARE OF POPLARS IN NATURAL STANDS

The importance of natural stands and the way in which they may be tended are closely related to the types of poplar and the proportion of the vegetation which they occupy. Many stands which can be seen today no longer resemble the initial stand; in fact, the finest specimens have nearly always been felled, particularly when they are localized in small areas. *P. nigra* in natural form is characterized in innumerable parts of Europe by a broad, ill-shaped crown, and a short trunk marred by burrs or knob-like growths. Little value is therefore attached to it and it is virtually never cultivated. The same is true, with only a few exceptions, of *P. alba*, *P.* x. *canescens*, and many other natural hybrids of this group, although they may not be completely lacking in technical qualities. However, these poplars are capable of establishment in soils of poor quality — too arid or too wet — which would not be suitable for cultivated poplars, and for this reason they deserve more attention from silviculturists.

P. euphratica is often to be seen in Syria with a bent, nearly always forked stem, which cannot be used as industrial timber. It is not a tree which appears to have a future, and silviculturists prefer " Roumi " and " Hamoui " poplars. They are content to let it grow on land which is regularly flooded and on which no other form of cultivation appears possible. Moreover, the old stands decrease in value, and there is an increasing tendency to exploit them as coppice on short rotations of one or two years for the production of firewood. The present trend in Syria is toward the introduction of cultivated poplars to meet bulding and industrial needs. In Iraq, the vast dense forests which formerly grew along all the watercourses have been completely destroyed to provide the country with firewood. Parts of the stands which are difficult of access have become state property. Furthermore, because of the use to which they are put by the rural population, the trees in Iraq are of small dimensions.

Aspen is receiving increasing attention from experts and foresters because it is a tree which can survive in poor soils and in unfavorable climatic conditions. Much research into its physiological behavior and morphological characters has already shown that there are forms suited to long days and others to short days, and that there is a lowland strain, often of poor habit, and a more satisfactory mountain strain. In northern regions the interest in aspens is increasing, since they supply the timber industry with a raw material which is much in demand. Natural stands of well-grown trees are managed according to modern cultivation methods, with a view to improving the quantity and quality of the trees. Special study is being given to the possibility of harvesting several crops from a single stand.

In America, too, the aspen is increasing in importance, not merely as a transitional species but also with a view to keeping it permanently under cultivation on certain sites. It is, nevertheless, cultivated less intensively than in Europe, where selection thinning is more rigorous. In the region of the Great Lakes it is possible to obtain a yield of 296 cubic meters per hectare at the age of 50 years, on good soils.

American black poplars (*P. deltoides*) which have survived the natural selection process, are of fine habit and are notable for their rapid growth rate. They are therefore certain to give good seed and suitable material for hybridization. Not very long ago American extraction practices amounted to a selection thinning in reverse, that is, trees of market value were felled and misshapen trees were left. Fortunately, today, the U. S. Forest Service is trying to overcome this destructive practice and is beginning to advocate the principle of improvement fellings. The aim is to improve the timber capital of the forest and to sustain the production of timber of market value, based on natural regeneration. This latter aim only seems likely to succeed when the soil is devoid of all other vegetation and the growth of the young plants during their early years is not hindered by weeds.

To sum up, it can be said that the status of natural stands is not unimportant, and if some countries give them scant attention in spite of their position in the rural economy, other countries are nevertheless giving considerable thought to their future.

Natural stands receive little maintenance: in fact, for much of the time the trees are left to grow untented. Improvement fellings are sometimes carried out and the finest specimens are pruned. For example, in France, in the Rhône Valley, natural stands of *P. alba* and *P. nigra* are clear-felled at the age of 25; the stands are restocked by root suckers, coppice shoots and some seeding. A cleaning is carried out after 12 years, which leaves only the best 1,000 stems to the hectare to constitute the future crop. In the case of aspens, they are usually clear-felled, sometimes leaving some trees standing as a reserve. Natural regeneration is stimulated by burning the felling site.

B. Cultivation of poplar in alluvial forests

Poplar cultivation is especially successful in alluvial forests, which in fact is the natural habitat of this species. The broadleaved forests which are to be found in these regions are nearly always bushy and impenetrable. However, in them can be found also, in small groups, stands with the appearance of high forest in which valuable light-demanding broadleaved species (oak, elm, alder, ash, maple, walnut, tulip tree, mulberry, plane, etc.) shelter an understory and intermediate story of secondary shade trees and bushes which protect the soil. The inadequate draining of flood waters and stagnant subsoil water turn huge areas of alluvial forest into virtually unproductive marshland.

Alluvial forests could hold first place for productivity, at least in temperate regions, even if their existing condition and yield do not support this claim. Besides being nearly always overexploited, these forests are as a rule completely neglected from the silvicultural point of view. They have habitually been left unmanaged (extraction of reeds, grass and forest litter) and also exposed to excessive grazing by cattle and game. Exploitation in alluvial forests is restricted chiefly to felling (sometimes clear-felling) coppice or groups of high forest, but timber production has often been of only secondary importance compared with the forest by-products. Hence the yield and growth rate have diminished and all reserves have been exhausted in proportion to the increase in the collection of litter and decaying vegetation. The forest economy is exhausted in the production of small firewood, and the once dense forests, now derelict, are considered virtually worthless, although they were once capable of yielding valuable broadleaved timber. With the conversion of simple and mixed coppice to high forest the alluvial forest could, more efficiently than any other kind, help to increase timber production and, in conjunction with expanding poplar cultivation, help to meet the shortage of softwoods in Europe, in the Midwest of the United States and even locally in the Near and Middle East.

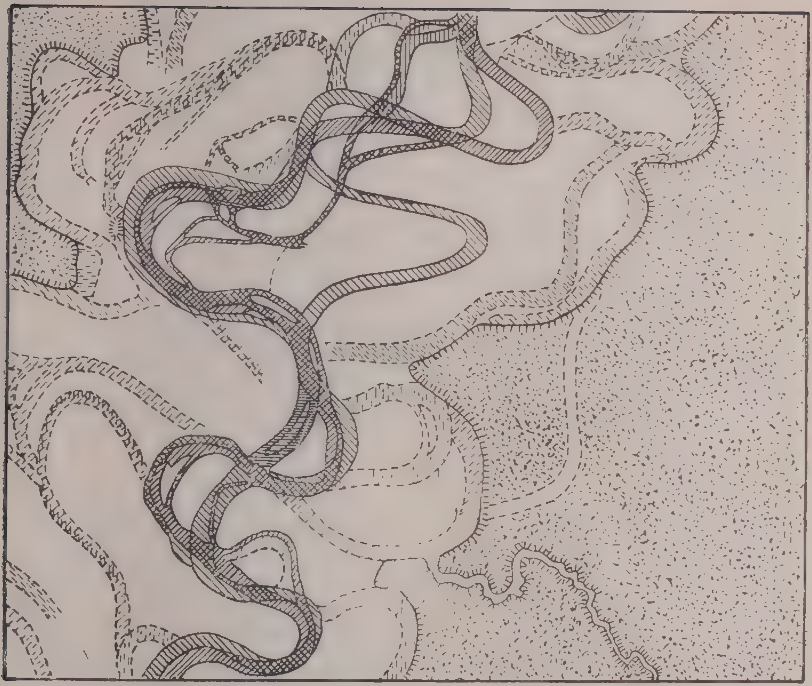
In western Europe alone, it would be possible at a cautious estimate to produce, 20 years hence at the latest, over 8 to 10 cubic meters more timber a year and supply a regular flow of softwoods to the market.

CHARACTERISTICS OF THE ALLUVIAL FOREST

Site characteristics

These forests occur in the alluvial — rarely diluvial — parts of valleys and on plains where there are lakes, rivers and streams, likewise on material deposited by the latter. They are affected by changes in the level of the water table. Certain areas are regularly flooded. Subterranean water also occurs here and there, while other areas on the other hand are distinctly dry and even show steppeland characteristics. The fluctuations of the water table affect the growth of the species and are a determining factor in the productivity of alluvial forests.

The soil of these forests is composed of river deposits and is formed in the same way almost everywhere. When the river is in spate, whole areas of alluvial forest are flooded. The huge volume of water spreads out, seeking to carve out fresh channels, soil is swept from one place to another and the water splits into a vast network of winding streams be-

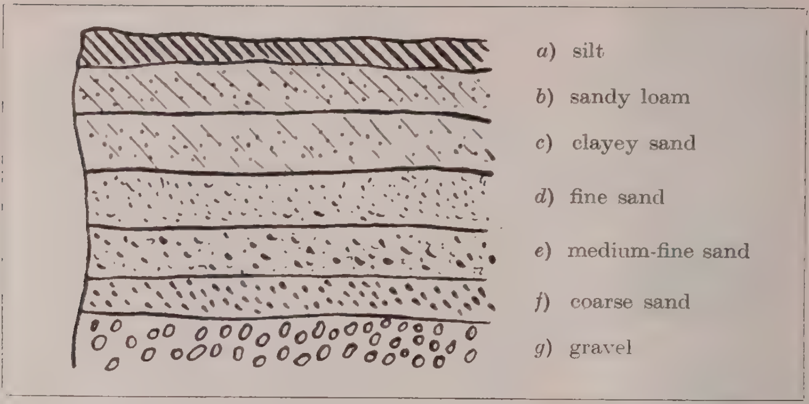


Courtesy *F. W. Bauer*

tween innumerable small gravel banks. Pebbles, gravel, river sand and silt are brought up by the current and both large and small gravel banks block its passage. Parts of the original watercourse are filled up, so that the forest presents a confused system of old and new river beds, among which a large variety of site conditions are to be found (*see* sketch above).

Banks of dry gravel and stones flank the permanently wet silty deposits, which are several meters deep. A difference of level up to 2 meters in a small area is quite common. The theoretical and systematic profile of the soil of alluvial forests is as follows: silt, sandy loam, clayey sand, fine sand, medium sand, coarse sand, gravel (*see* sketch on p. 226).

However, these strata are never found regularly nor in their entirety. In fact, after flooding, the layers become mixed. Gravel layers of varying depth pass through the silt and sand and, together with fluctuations of



Courtesy ***F. W. Bauer***

the water table, give rise to a very wide variety of site conditions. The following are the factors which determine the silvicultural techniques and management:

- *a*) position (inside or outside the flood zones, on the perimeter exposed to the full force of the flood waters or on sites where the water does not drain away);
- *b*) proportion of land (level of the water table and drainage of subterranean water);
- *c*) depth of soil (thickness of the layer through which the trees can develop their roots);
- *d*) physical structure of the soil, particularly the proportion of heavy and light clay;
- *e*) proportion of calcium in the soil ($CaCO_3$ content, and if none, CaO or MgO content);
- *f*) pH reaction of the soil (presence of acids).

Different aspects of the site

The appearance of the site depends on the different types of alluvium, the variations in its physical and chemical composition and, in particular, the water supply.

Alluvial flood zone

Where this zone meets fall water at the surface there is often a border consisting of a vigorous growth of reeds, where deposits are left by each flooding. The deposits, together with the reed bed, block up parts of rivers and lakes. Bushy willows, which are the first to be established, are followed later by willows which attain larger dimensions. Poplar and plane seedlings may also appear but can only survive in a dry year.

Softwood zone

These sites are regularly flooded (sometimes for weeks and months, but are nevertheless without water for the greater part of the year, which allows trees to become established. Typical species are willow and poplar.

A distinction is made between sites exposed to the full force of the flood waters and those from which the water does not drain away.

Hardwood zone

These sites are flooded only occasionally and then only for a short time; they are therefore suited to species which are less tolerant of flooding. The productivity of these sites varies considerably according to:

a) level of the water table, its fluctuations and movements;
b) depth of the soil;
c) physical structure of the soil, that is, the proportion of the fractions measuring less than 0.01 millimeter.

Typical species (on moist sites where the water table is high) are ash, and in America certain types of maple, in Eurasia, plane; this zone overlaps to a certain extent with the preceding zone. Virginia creeper (*Parthenocissus quinquefolia* Planch.), which grows abundantly in America, has established itself on this type of site in many valleys of Europe, as has box elder (*Acer negundo*).

On fresh sites, typical species are ash, elm, in Europe sycamore, in America *Liquidambar* and certain types of hickory.

On dry sites (where the water table is low), species include hornbeam, birch, cherry and in Europe Norway maple, white poplar, etc.

Marshy zones

These sites include miry soils and low-lying marshes where the typical species is alder.

Zones with variable moisture relations

Local accumulations of water saturate the ground, in places impeding growth, particularly in soils which are normally heavy. Such soils are either saturated over a period of months or else completely dry; they are, consequently, the most difficult to cultivate of all alluvial forest sites.

Stages of vegetation

As has been said, the alluvial forest is characterized by different stages of vegetative development. On the newly formed gravel and pebble banks bushy willows and tamarisk are the first to take root. When finer alluvium has been deposited, willows of larger sizes develop concurrently with poplars. In Eurasia, this association consists of *Salix alba* with *Populus nigra* and *P. alba* and sometimes *P. euphratica*; and in North America, *Salix nigra* with *Populus deltoides* and sometimes *P. tacamahaca*.

When the ground level has been raised sufficiently by successive deposits and is no longer subject to regular flooding, the willow-poplar association gives way, little by little, according to soil and climate, to moderately moist forests and sometimes even distinctly dry forest types.

Economic importance of the different poplar sections and species

European black poplar (*Populus nigra* L.)

On good soils black poplar reaches a diameter at breast height of more than 100 centimeters in 50 years, with a height of up to 35 meters and volume ranging between 8 and 10 cubic meters of good quality timber. From the silvicultural point of view, black poplar is noted for its easy adaptability and capacity for fairly good growth even on soils liable to be covered with sand, gravel and pebbles.

American black poplar (*Populus deltoides* Marsh.)

The American black poplar fulfills the same role along rivers in the east of the United States as the preceding species does in Europe.

It generally attains greater dimensions, at least in height; its habit is also finer than the preceding and is not marred by burls. It appears to be more exacting as to soil fertility and moisture.

Cultivated black poplars

These poplars are only of importance in Eurasia. Fastigiate forms of black poplar (particularly *P. nigra* 'italica') have been typical of many valleys for several hundred years, whereas it was only in the second half of the nineteenth century that Euramerican hybrids of the preceding poplars were introduced into alluvial forests. They were remarkably successful and easily surpassed the native poplars in growth increment, production of industrial usable timber and utilization value of rough timber.

Aspens

Both in Europe and America, aspens are found only spasmodically and are generally of much less importance in alluvial forests, at least in temperate regions.

White poplars

These do not attain the size of black poplars but may nevertheless be of interest in southern regions, as they are relatively drought-resistant and little affected by wind and soil salinity.

Gray poplar (*P.* x *canescens*), like aspen, is more at home outside the alluvial forest.

Poplars belonging to other sections and which sometimes constitute alluvial forests, for example, *P. euphratica* in the Near East, are only occasionally worth propagating to improve the forest yield.

ENRICHMENT OF THE ALLUVIAL FORESTS OF THE MIDDLE RHINE VALLEY

It has already been said that alluvial forests are almost completely neglected from the silvicultural point of view throughout the world. The way in which they can be managed is best seen from the following example from the middle Rhine Valley in Baden, where the systematic improvement of coppice has been carried out with very successful results for more than 50 years.

Site units

In simple coppice and coppice with standards the only cultivation required is to fill in any gaps that may occur; in the course of this operation the upper story is completed by introducing a number of plants. At this time generally no account is taken of site variations. With the conversion of coppice to high forest the site conditions must be taken into account with the choice of species and the purpose of production. The only method of achieving this is to divide the area into units.[6] Careful but not too rigid separation into site units is therefore the most important task in the management of the alluvial forest. It is extremely rare for the limits of the plots or units to be clearly visible on the ground; they generally merge imperceptibly into each other and can only be distinguished by the different behavior of the trees. These areas, which have been described above, are summarized here:

Flood zone

This is linked to the tree water by an almost impenetrable reed bed (*Phragmites communis*).

Softwood zone

Typical species are willow and poplar. The height, fluctuation of the water and its dispersal, determine the choice of species, purpose of cultivation and silvicultural technique.

Hardwood zone

Typical species, on moist sites where the water table is high, are ash; on fresh sites, pedunculate oak, elm and sycamore; on dry sites, where the water table is low, hornbeam, Norway maple, cherry, white poplar and birch.

Marshy sites

These include low-lying marshland, old river beds and ground which is permanently wet. The typical species is alder (*Alnus glutinosa*).

Sites with variable moisture

These sites require special care. The most suitable species up to the present time has proved to be spruce, which has been partially successful although quite outside its natural habitat, and it has improved the soil, after previous liming. Poplar cultivation on these sites can at first only be experimental and with specially selected species. Experimental plantings have already met with partial success and are worthy of note. However, the results are not yet conclusive enough to justify recommending poplar cultivation in general on such soils.

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[6] *Site units:* plots of forest land where the site factors are identical or comparable to a degree in which they can be managed for the same purpose and according to the same principles.

Vegetation

The alluvial forest, as indicated above, is characterized by various stages of vegetation. On the newly-formed gravel and stony banks bushy willows and Hippophae are the first to be established. After the deposition of finer alluvium, follows white willow, white alder and black poplar, as well as shrubs such as barberry (*Berberis vulgaris*), privet (*Ligustrum vulgare*), blackthorn (*Prunus spinosa*) and dogwood (*Cornus sanguinea*). The silt banks in the proximity of subterranean water are quickly covered with thick reeds. Once the flood stage is passed, seeds of willow and black poplar carried by the wind are deposited on the soil. When the soil is no longer exposed to regular flooding, the willow gives way to wet or dry oak hornbeam forests, according to the nature of the soil and subsoil. In places, by strange contrast, typical steppeland pine forests spring up.

The genus *Populus* is represented in all natural forest associations: it is even to be found on extremely dry sites. Black poplar (*Populus nigra*) and white poplar (*Populus alba*) appear in groups, whereas the pyramidal poplar (*Populus nigra* 'italica') is chiefly found as a single tree and is not cultivated. In places, gray poplars (*Populus canescens*) are also found growing naturally either as isolated trees, in groups, and even in small stands (*see* Figures 102 to 105).

Black poplar (*Populus nigra*). Due to its properties and high timber yield, black poplar takes the lead among cultivated native poplars. A form of black poplar worthy of note from the economic point of view is "figured poplar," distinguished by the strong cone-like burrs which are found on the bole. The timber is used for the manufacture of special veneers.

From the silvicultural point of view, black poplar is notable for its wide adaptability. On distinctly dry sites, for example, in the steppe-like regions of the upper Rhine, it has proved to be the most drought-resistant species.

White poplar (*Populus alba*). White poplar also grows satisfactorily on dry sites. It should, therefore, be preferred for sites where it is found growing naturally. It is particularly useful as a preparatory species to

Poplars on different site types

(Figures 102 to 105)

Courtesy *F. W. Bauer*

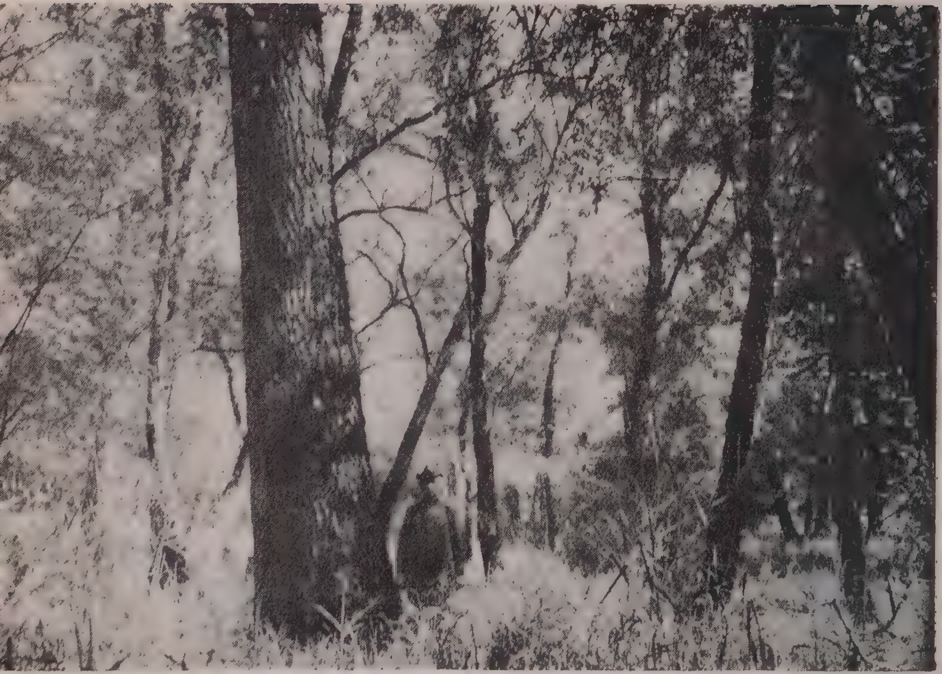


Figure 102. - Poplars in a flood zone, exposed to flood waters over a period of weeks.

Figure 103. - Poplars on a wet site, with a permanently high water table.

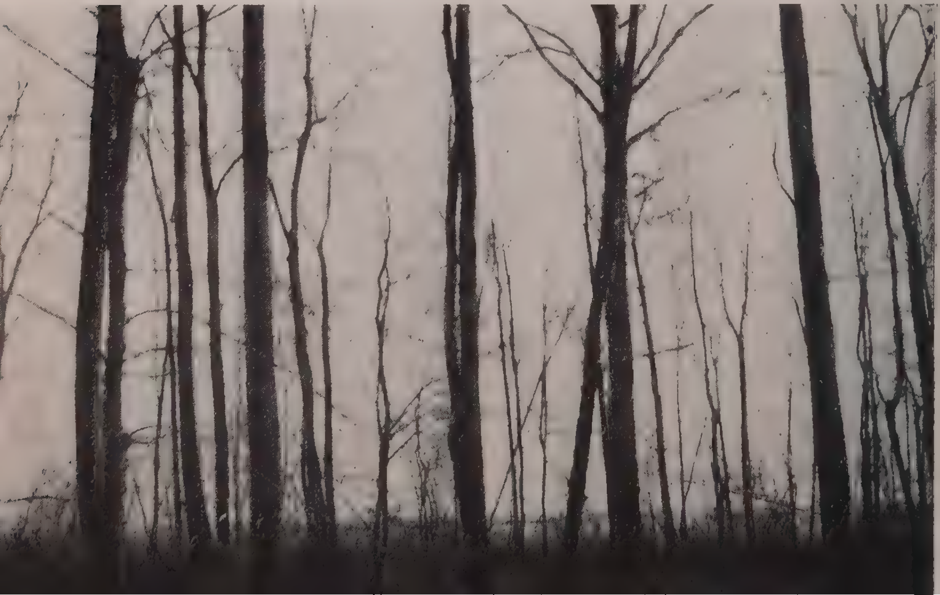


FIGURE 104. – Poplars on a dry site.

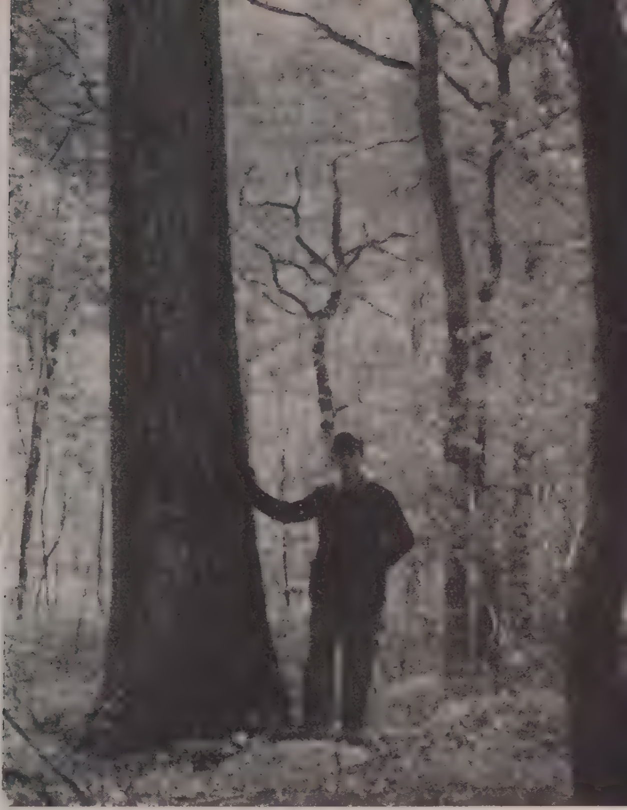
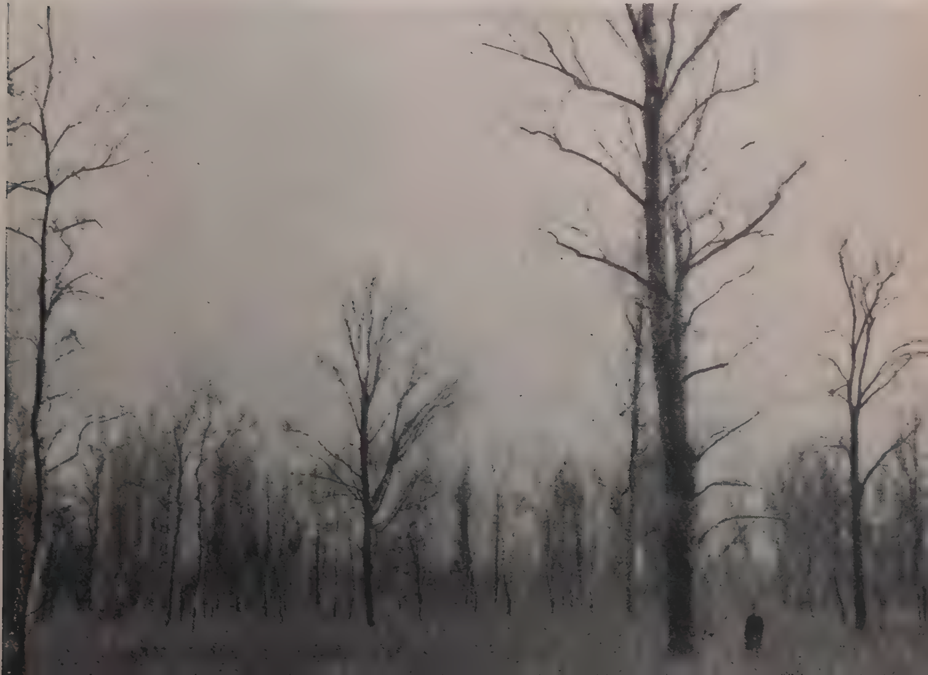


FIGURE 105. – Poplars on the "Steppe" grasslands of the Upper Rhine Valley.



protect some of the special broadleaved trees, sensitive to frost, such as black walnut (*Juglans nigra*) and ash (*Fraxinus excelsior*). The diameter of the latter should not be allowed to exceed 40 to 45 centimeters, since with larger girths the danger of cup-shake increases and the stem loses its value.

Aspen (*Populus tremula*). Aspen, like gray poplar (*Populus canescens*) is only found spasmodically. The value of this species is considerably inferior to that of other poplar types of the alluvial forests and of valuable willows.

Pyramidal poplar (*Populus nigra* 'italica'). The distinctive character of pyramidal poplar gives a particular appearance to many of the plains of Europe crossed by rivers. The value of the rough timber and the volume yield are, however, so low that its cultivation is not profitable.

Euramerican hybrid poplars (*P.* x *euramericana*). At the beginning of the second half of the nineteenth century, Euramerican hybrids were introduced into the alluvial forest under the name of "Canadian poplars," and were remarkably successful. It is not rare for 50-year-old poplars in alluvial forests to produce 12 cubic meters of good quality timber and 3 cubic meters of pulpwood out of a total volume of 20 cubic meters.

An astonishing example of growth is provided by a poplar in the vicinity of Karlsruhe in the Rhine Valley; it reached the age of 136 years in a perfectly healthy condition, with a height of 38 meters and a diameter of 220 centimeters at breast height. This, "the largest Canadian poplar in Europe" was specially preserved until it had to be removed to allow construction of a railway. It yielded 26 cubic meters of large-sized timber, 35 stores of stacked wood and 250 faggots, in all a total of approximately 58 cubic meters.

Felling series of poplar

The value and quantitative yield of a single tree are not sufficient to allow either the economic worth of a species or its silvicultural importance to be determined. It is the vigor of the stand as a whole, the proportion of timber in the different age groups, the utilization of the various produce classes and the length of the productive growing period which are the deciding factors. Comparison of the felling series for poplar with that of other species shows the marked superiority of poplar.

It is also illuminating to study the short- and long-term cultivation of poplar in the forest (Plot 5). Hence, the type of forest association suited to flood areas, composed of 90 poplars and 10 willows, with an understory of willow pollards, gives the following data for volume and revenue (Plot 4):

Rotation	Area	Estimated average increment	Normal expected yield	Produce classes						Gross revenue in DM		
				Logs[1]		Stacked wood	Percentage industrial timber	Large-sized firewood	Small-sized firewood	Total	Per hectare	Per m³
				2nd and 3rd categories	4th to 6th categories							
years	*hectares*	*cubic meters*										
25	25	15	340	110	80	50	70	30	70	18 000	737	54
50	50	18	800	80	350	140	75	90	140	59 000	1 200	75

[1] 2nd category = 21 — 30 cm. ø; 3rd category = 31 — 40 cm. ø; 4th category = 41 — 50 cm. ø; 5th category = 51 — 60 cm. ø; 6th category = > 60 cm. ø.

It is only with rotations of at least 40 years that the entire benefit can be obtained from maximum increment, above all utilizing to the full the rapid increase in valuable produce and putting on the market mainly first-quality stems. In view of the varying market conditions prevailing in different countries, it is not possible to apply this statement universally.

Silvicultural management

While the intensive cultivation of poplar in stands or in lines outside the forest is on the whole along agricultural lines, its cultivation in the forest must be dictated by the principles of silviculture and by forestry practices. Governed in time and space by a technique which applies to a whole felling series, the stand is part of an entity dependent on biological and ecological conditions; hence the exploitation of these stands is subject to restrictions which at the same time constitute their safeguard.

The forest economy has created the idea of a "forest-plant association," which is the cornerstone of modern silviculture. The biological and ecological requirements of this association have proved the strongest force in the cultivation, management and exploitation of forest stands. These needs prevail during the establishment and development of the stand, and in a forest economy based on silvicultural principles, therefore, the following practices should be avoided:

- *a*) pure plantings of poplar contrary to natural conditions consisting of a single clone;
- *b*) establishment of single-story high forest, producing a closed stand in a horizontal slide;
- *c*) felling of large areas;
- *d*) attempts to cultivate poplar in selection forests.

Former practices

Most of the alluvial forests are treated as simple coppice or coppice with standards. Felling rotations of ten years and over are still in practice today, that is to say, the forest receives practically no attention. Stands capable of producing 10 cubic meters or more of timber annually per hectare yield barely one cubic meter, and production is concentrated primarily on poor quality firewood. However, since on such valuable sites the aim of the forest economy should not be limited to the production of fuelwood, there is an urgent need to switch from extensive exploitation of coppice to that of high forest.

The cultivation of simple coppice and coppice with standards is not merely uneconomic but entails grave silvicultural dangers. Such practices, employed over decades, drain nourishment from the soil by excessive fuelwood production. Furthermore, felling on short rotations encourages the seasonal invasion of weeds and hence, indirectly, the gathering of forest litter. With the exception of sites which are regularly flooded, coppice cultivation inevitably leads to destruction of the forest. The conversion of coppice with standards to high forest is as important from the economic point of view as from the silvicultural viewpoint. The intensification and improvement of silvicultural methods necessary to achieve this also entails an expansion in the cultivation of poplar, bringing this species to the fore in the alluvial forest.

Future method of treatment (coppice conversion and management of high forest)

Introduction of poplar on felling areas in simple coppice and coppice with standards. Felling of coppice with standards after the underwood has been cleared is directed at all those trees in the upper story which have attained maturity but which are not capable of yielding good timber, that is, all the unhealthy trees with arrested growth. On the other hand, the fine specimens capable of producing timber but not yet of felling dimensions should be preserved as long as possible in groups, so as to facilitate conversion and natural pruning. The gaps are restocked with poplar at a spacing of about 10 meters, the normal distance in high forest; if necessary, the understory should be completed with shade trees. These widely spaced trees need careful tending. Coppice shoots should be thinned early so as to include them in the under and intermediate stories. In this way, at little cost, high forest in which poplar predominates will be successfully and speedily established and future treatment will aim at bringing it to maturity. A large number of experimental plots managed by the writer show the excellent and speedy results which can be obtained in this way. The "surface type" No. 1 is particularly noteworthy. After the last felling in 1915, the area was planted with widely spaced poplars, due to the lack of labor and other plants. Nine years later, when the stand still had the appearance of coppice with standards, the communal forest came under new management. By 1932, due to the introduction of poplars, it had already taken on the appearance of high forest, and by 1950 the conversion was complete (Plot 1).

Role of poplar in coppice conversion. The aim of the conversion of alluvial forest should be to establish simultaneaously with the first age class of the stand (1-20 years), the second class (21-40 years), third (41-60 years) and fourth (over 60 years). In so doing, the conversion is greatly speeded up and the growth of timber for industry increased. The necessary fellings carried out during the process are known as "conversion fellings" and their object is to transform the coppice with standards, or suitable parts of the coppice (taking into account their condition), into stands of compensating age with the character of high forest, and to incorporate them into the second (21-40 years) or third (41-60 years) age classes (*see* Figures 106 and 107).

These fellings must be carried out very carefully and repeated as a rule three or four times until the conversion is complete. They should also be extended to trees in the upper story which are unsuitable for timber production (that is, dying or overmature trees), as well as all those which at first sight seem unlikely to survive the conversion. Areas which are unsatisfactory and unsuitable for conversion should be felled and restocked with poplar, similarly with areas which have been thinned. Only aphototropic poplars are suitable for restocking: that is, poplars which are capable, without loss of straightness, of filling the gaps under the canopy of the dominant trees. An excellent example of this is given in "surface

Conversion felling and restocking of gaps with poplars
Canton of Offenburg

(Figures 106*a* to 107*b*)
Courtesy *F. W. Bauer*

Figure 106 *a*). – Left: main stand consisting of 35-year-old ash restocked with poplars, now 15 years old; conversion not yet complete.

Figure 106 *b*). – Right: 38-year-old stand of ash and alder restocked with poplars (18 years old); conversion complete.

PERCENTAGES				
Species	Volume	No. of stems	Forest cover	Proportion of timber
Poplar	66	18	50	82
Ash	24	49	20	14
Alder	6	16	10	3
Oak	3	1	—	1
Elm	1	16	20	—

Figure 107 *a*). – Left: high forest of 70-year-old ash and alder obtained by conversion, with a few individual trees or groups of 45-year-old poplars.

Figure 107 *b*). – Right: former coppice with standards converted to high forest: poplars 45 years old; ash 70 and 95 years old; and oak 95 and 120 years old. Volume per hectare, 415 cubic meters.

type" No. 2, in the State Forest of Offenburg VI/17, which shows the final stage of a successful conversion, in which gaps were planted up with poplars.

Conversion of unsuitable stands and creation of new poplar forests. It is not unusual for good or even excellent alluvial forest sites to be overgrown with impenetrable scrub and very dense climbing plants. One

CONVERSION OF UNPRODUCTIVE STANDS
(Figures 108 to 110)
Courtesy *F. W. Bauer*

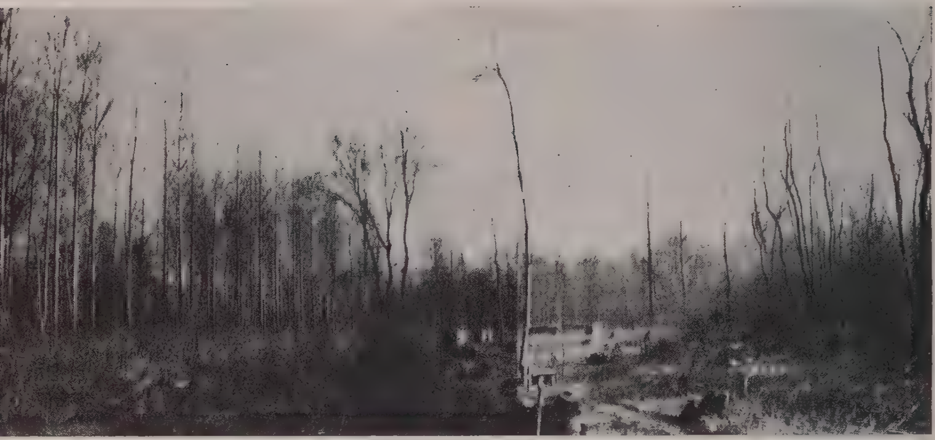


FIGURE 108. – Conversion of unproductive stands on alluvium into poplar stands by felling and replanting: left, young poplar stand; center, felled area (planted up with poplars); right, stand which has reached maturity.

often finds on old rotting stumps, shoots of alder, ash, poplar (suckers of white poplar, alder and aspen) and occasional trees generally with short trunks and many epicormic branches (for example, oak, elm, alder, ash, black poplar, willow and other species). In spite of excellent site conditions production barely amounts to 1 cubic meter of timber per hectare annually (*see* Figures 108 to 110).

The clearing and replacement of these worthless forests by a rationally managed planting is of the greatest urgency; each year's delay means loss of increment and revenue. On such sites, which are generally difficult to cultivate, poplar is the most suitable species for the speedy and successful establishment of a valuable stand, able to take full advantage of the site qualities.

Improvement of the Rhineland forest: control measures against the mosquito pest; poplar cultivation. In those areas of the alluvial forest which are regularly flooded and become saturated with water, there are parts where bushy willows, old lean willows, alder stumps and branchy black poplars form the only cover, although the soil is a fertile silt. These sites are submerged at every flooding and remain so for months, as the water cannot drain away. Stagnant water, which is low in oxygen, completely halts the growth of the tree and any attempt to turn this fertile

FIGURE 109. – Subsequent stand of poplars; increment of timber more than 20 cubic meters per hectare per annum.

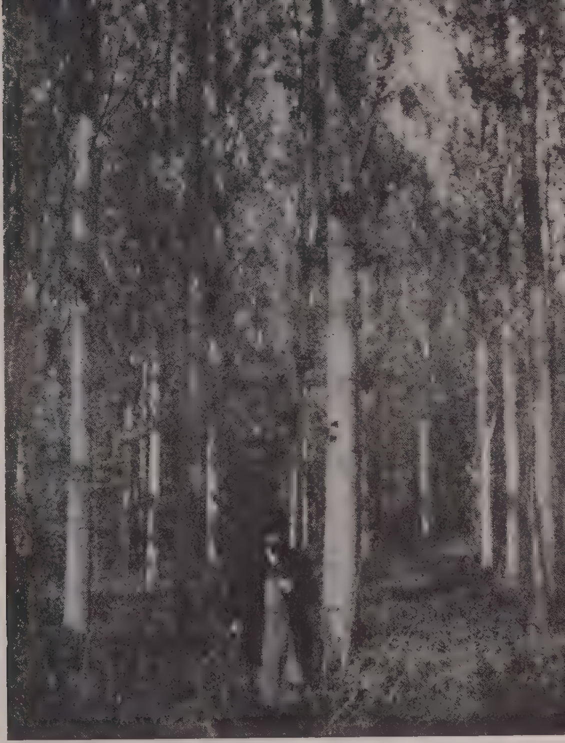
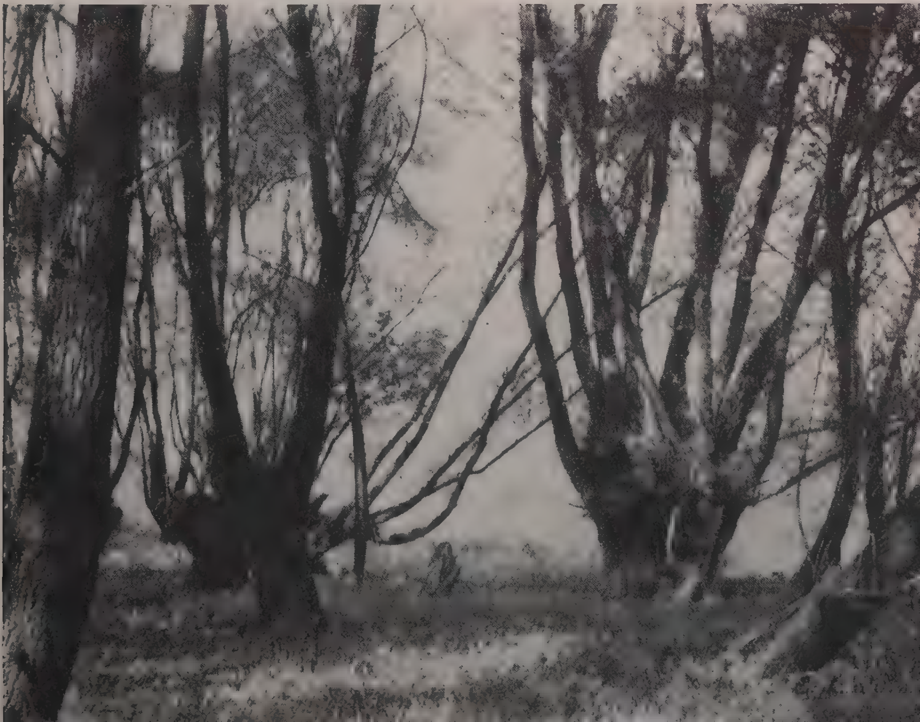


FIGURE 110. – Unproductive stand on deep silty soil; no utilizable timber produced.



soil to account, from the point of view of the forest economy, will be useless until the flood waters are drained off (*see* Figures 111 and 112).

The drainage ditches will serve at the same time as a control against mosquitoes, which are a national pest on almost all plains where there are large and small rivers and lakes. Urgent measures are needed to combat this pest over the vast, heavily populated plains of Europe. The construction of an extensive drainage system would get rid of the surplus water and destroy the breeding grounds of the mosquitoes. The land thus reclaimed would without doubt constitute the most productive of poplar sites. "Surface type" No. 2 shows the successful results which can be obtained (Plot 2).

Silvicultural aims (*see* Figures 113 to 121)

The object of poplar cultivation in the alluvial forest is the production of large-sized timber; the produce most in demand is the log for veneering. The aim should be to produce stems having a diameter of 70 to 100 centimeters at breast height, a size obtained after 40 to 60 years (50 years). To be of market value each stem must have the following qualities:

a) *form of the stem:* straight-grained, upright, cylindrical;

b) *shape of the crown:* regular, conical, symmetrical; its length should not be less than 40 percent of the height of the tree during the first half of the rotation, and not less than 25 percent during the second;

c) *wood structure:* free of knots (the core not more than 12 centimeters); regular, concentric growth rings.

The high quality requirements of such timber production can only be met if the growing conditions of the poplar from the onset are such that its crown can develop freely, shade trees protect its stem and early pruning is carried out so that dry snags do not form.

It is not possible to produce poplar wood of high quality in coppice with standards, in selection forests, or in pure poplar stands consisting of a single story, where the closure of the canopy inevitably deforms the crowns and from which the poplar never recovers. Any measures taken later only result in further distortion of the remaining poplars. In fact, the remaining trees, in their efforts to avoid competition from their stronger neighbors, become curved and have twisted grain. In the struggle for

AMELIORATION OF ALLUVIAL SITES – ANTI-MOSQUITO MEASURES

(Figures 111 and 112)
Courtesy *F. W. Bauer*

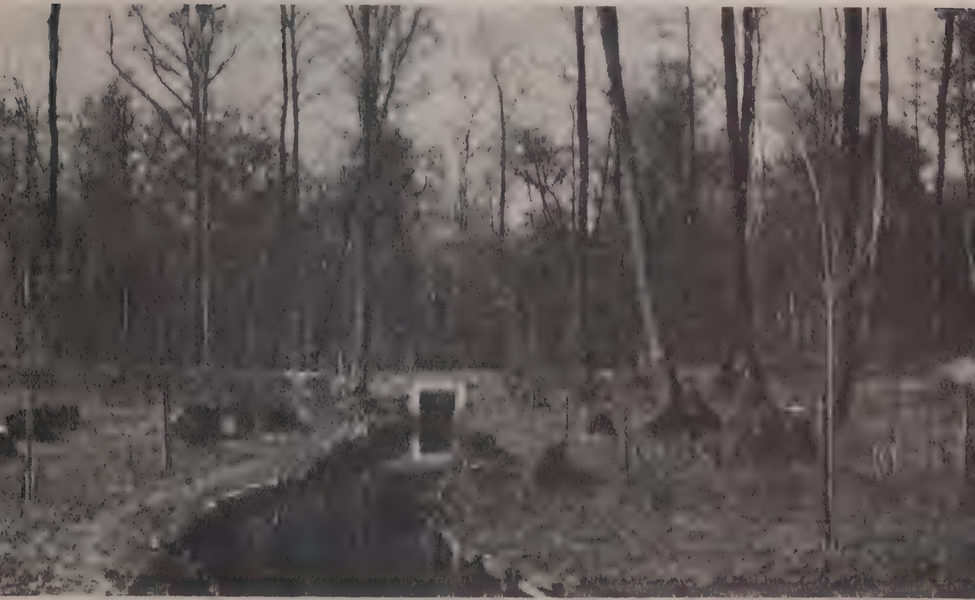
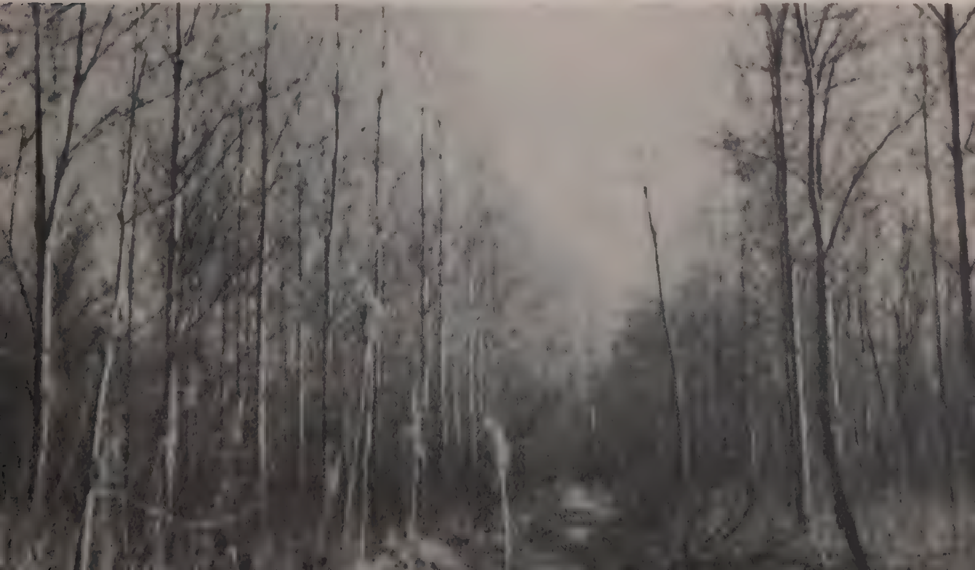


FIGURE 111. – Draining a stagnant pond and replacing with poplars.

FIGURE 112. – 20-year-old poplars on land still in state of amelioration; that is, on unproductive, marshy soils and mosquito-breeding grounds.



SILVICULTURAL OBJECTIVE – STOCK DESIRED

(Figures 113 and 114)

Courtesy *F. W. Bauer*

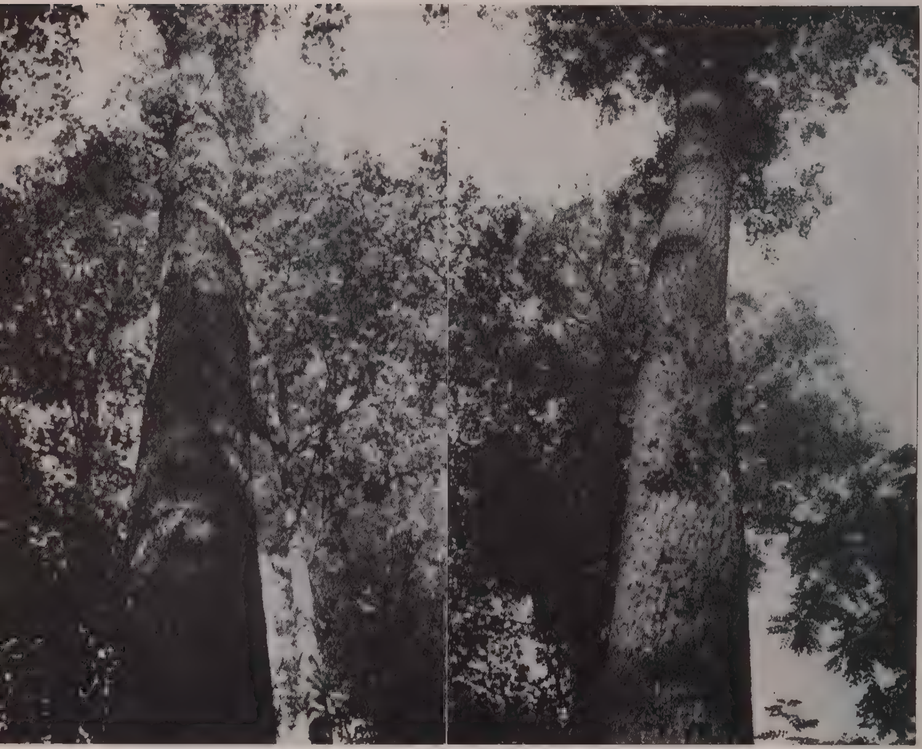


FIGURE 113. – Mature poplars.

FIGURE 114. – Left: line planting of 60-year-old poplars: (Average height, 40 meters; average diameter, 110 centimeters; average yield of choice timber and small-sized timber, 17.2 cubic meters; average yield of roundwood, 16.4 cubic meters.) Right: veneering log of 42-year-old poplars.

SILVICULTURAL OBJECTIVE – COMPOSITION OF STAND ENVISAGED

(Figures 115 to 117)

Courtesy *F. W. Bauer*

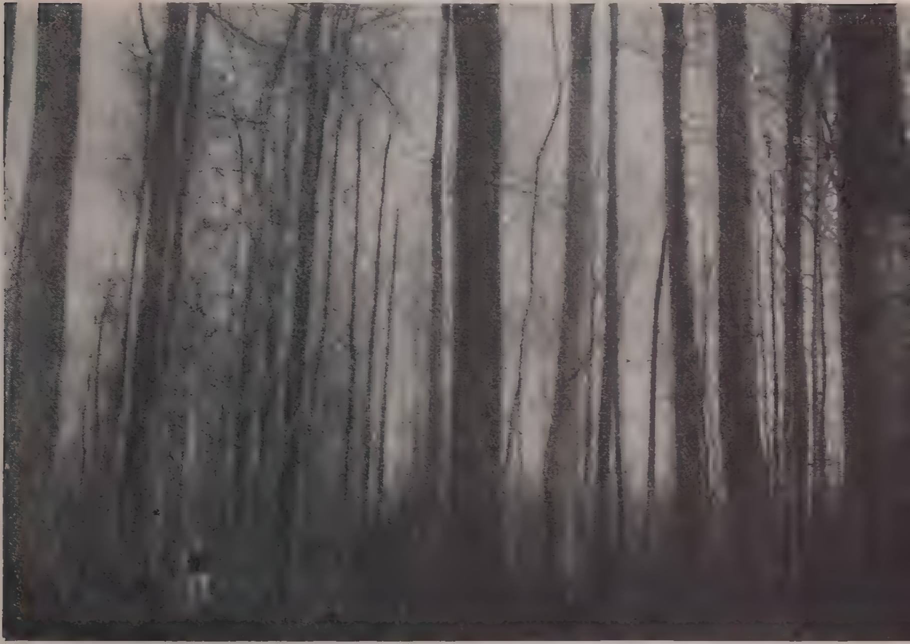


FIGURE 115. – Sample plots: final stand – young stand (before first thinning).

FIGURE 116. – 18-year-old stand after first thinning (yield from thinning, 60 cubic meters per hectare).

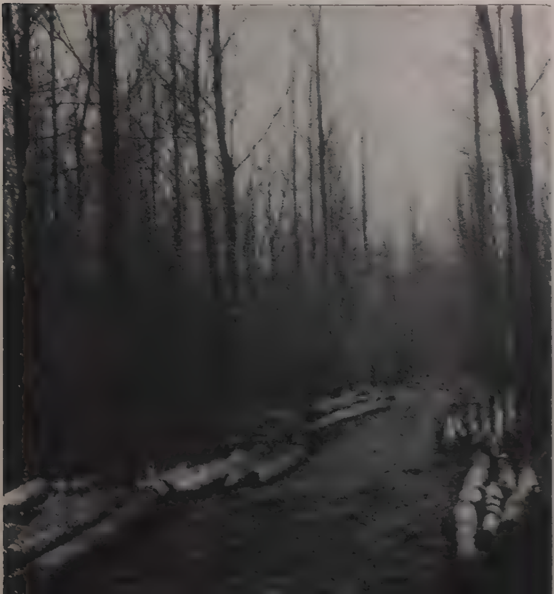
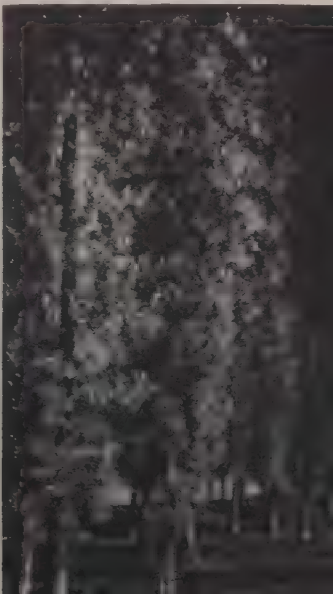


FIGURE 117. – Single-story stand; thinning was left too late and the stand rendered worthless by the growth of epicormic shoots.



RESULTS OF PLANTING TYPES OF POPLAR UNSUITED TO SITE CONDITIONS

(Figures 118 to 121)

Courtesy *F. W. Bauer*

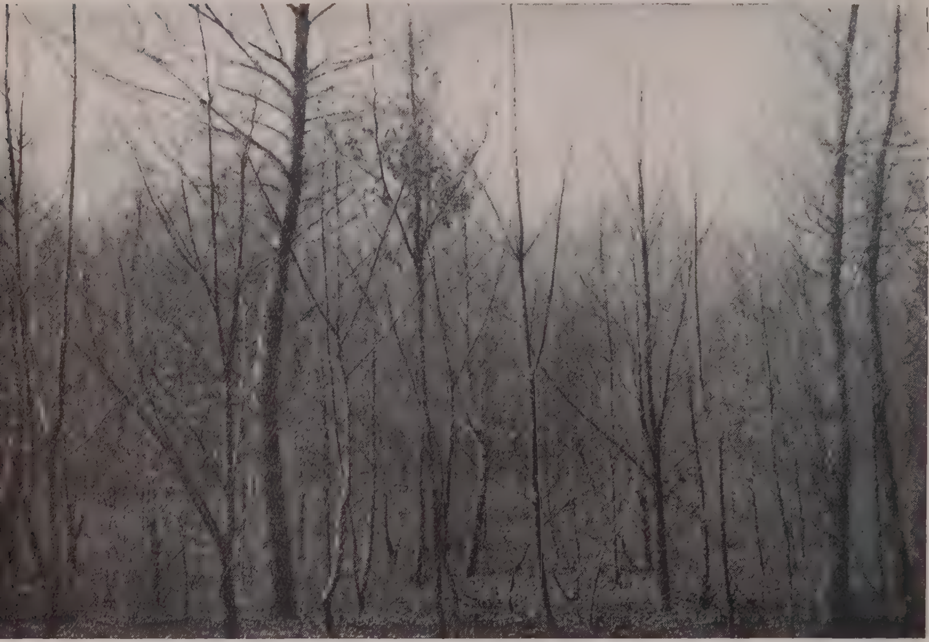
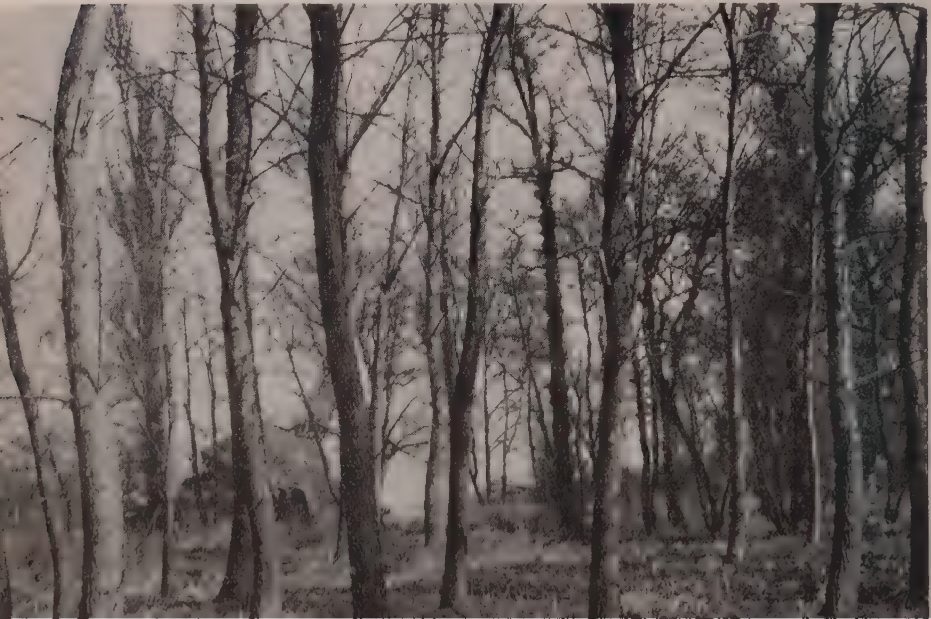


FIGURE 118. – Poor growth despite treatment and improvement of trunks and crowns.

FIGURE 119. – Stand composed of types completely unsuited to the site, in a region exposed to floods.



FIGURES 120-121. · Poplars sensitive to phototropism and therefore unsuitable for cultivation.

light, which is intensified after the canopy has closed horizontally, the crowns become asymmetrical, the growth rings excentric and the quality of the timber decreases; hence the success of the planting is threatened. Thinning the stand at a later age leads to the formation of epicormic branches, with harmful effect on the technical qualities of the timber.

The constitution of a stand with a single story and the subsequent horizontal closing of the canopy are contrary to the biological and ecological requirements of efficient cultivation and should therefore be avoided. It is only possible to obtain high quality timber if the stand is composed of several stories closed in the vertical sense. In this way the crowns have full access to the light throughout their growing period, while the stems on the contrary remain in the shade of the understory. Moreover, for the production of valuable timber, the canopy must close story by story and the species should be mixed. The stems can thus enjoy free growth from an early age in open conditions. Secondary species include, according to the site conditions, willow pollards, alder, hornbeam, lime, maple, red oak and plane. Only a stand composition such as this ensures that the poplar crowns have full light in which to develop perfectly symmetrically, and that the secondary species give adequate protection to the stem and to the soil, and so prevent the formation of epicormic branches and the invasion of harmful weeds.

Stand composition in several stories is therefore ideal for poplar cultivation, the aim being for poplars to occupy the upper story in an underwood of good secondary species. The realization of this object presupposes the fulfilment of the following conditions:

a) creation of new perfect stands, free of defects;
b) individual attention at an early age (pruning of the best trees);
c) consolidation of the understory (if necessary by pollarding);
d) early thinning.

" Surface type " (Plot 3) represents one of the sample plots showing this type of composition in its final stage.

However, with the production of good quality timber only, poplar cultivation is not fulfilling its economic task. Market analysis shows more and more clearly that the demand is veering increasingly toward small-sized timber. As has been said in the introduction, according to recent studies, European pulp requirements alone will absorb 40 to 70 percent of production in the next ten years, during which time the standard of living will rise by 30 or 50 percent. To this may be added new industrial needs of rough timber. In this respect, chemical processes as yet in the development stage offer particularly good prospects. The resulting increase in the demand for small-sized wood will create an even greater shortage of this type of produce.

Next to conifers, hybrid poplars provide an excellent chemical raw material superior in quality to all other broadleaved species. The composition and management of mixed poplar forests should therefore be directed to producing sufficient quantities of these valuable small sizes of wood. So long as the aim of poplar cultivation is to produce high quality timber on a 40-to-60-year rotation, such produce can only be obtained by thinning, which therefore should not be abandoned altogether.

Selective felling is necessary not only from the economic but also from the silvicultural point of view, in order to establish stands according to silvicultural principles, to ensure their productivity and to utilize the site to its best advantage. Research has shown that the prescribed felling diameter can only be reached in 40 to 60 years if each tree has a minimum growing space of 100 square meters. The ideal stand consists of 100 choice poplars which only attain maximum increment under open conditions when the final spacing is reached, at latest between the 30th and 35th year. The highest volume yield is obtained only if the stand is completely closed just before reaching felling age.

The under- and intermediate stories, whose role as auxiliaries is only to protect the soil and the stem, will have a greater influence if the number of stems is smaller, the crown broader and the tree more tolerant of shade. The minimum spacing of 2 to 3 meters must be maintained from an early age. With the auxiliary species at greater density, root competition increases, the water balance deteriorates and the struggle of the crowns for growing space is intensified, with the result that not only does crown development suffer but closure of the canopy story by story is also hindered.

The ideal poplar stand with several stories is composed as follows: in the predominating stand there are approximately 100 poplars to the hectare, with an understory of secondary tree species and shrubs; this ensures that the crown will receive light, the trunk shade and that air will circulate freely near the ground. There is, however, no general ruling or spacing. It is, rather, that the type of produce envisaged, the quality, rotation and poplar types used and the preparatory thinnings planned really determine the spacing. A spacing of 4 to 6 meters is recommended; less than 4 meters does not appear desirable, as it prevents the best composition of the understory and intermediate story, while more than 6 meters is generally uneconomic, since with rotations of 40 years and over, full use is not made of the growing space and the yield from thinnings is reduced.

Silvicultural technique

The aim and natural trend of extensive poplar cultivation is toward a stand composed of several stories, with poplar as the dominant species and with shade species in the lower and intermediate stories. Attempts to grow poplars as individual stems once they have reached felling age and to proceed with selective fellings has met with serious failure. Apart from the normal silvicultural disadvantages, the increment fell in less than 20 years from 100 to 30 percent and the value of the produce fell to 20 percent. With poplars more than with other species, the only effective treatment of high forest is by localized felling, that is, when the forest is composed of different age classes. With intensive methods, 20 to 30 percent of the area must be felled each year. Stands which are overmature or unsatisfactory are felled — these constitute the crop and "final felling;" the greater part of the stand, depending on age, is reared, shaped and cleaned — it is these operations which yield the "subsidiary products."

All operations must be directed to the end purpose, as any deviation causes losses. According to the age of the stand, a distinction should be made between cleaning, thinning, and selective and regeneration fellings in the high forest. Moreover, in the silvicultural treatment of poplar, these operations need to be strictly carried out at the appropriate stages in the growth of the trees.

Care of the new growth (second to fifth year)

Experience has shown, and the life of the stand confirmed, that the basis of maximum production can only be laid when the stand is very young, and that any negligence or omission at that time can rarely — in many cases never — be made good; in fact, two to three years elapse before perfect growth in the poplar is obtained. In stands of the same age, treatment should always be carried out in the autumn. Only at the end of the third year can it be decided whether the stool shoots, suckers and natural seeding are suitable to constitute the auxiliary species. If these are lacking, they must be introduced artificially. Only careful treatment of the crown will guarantee rapid growth in youth and a stem of the best form.

Cleaning (sixth to tenth year)

The young stand must be cleared of all unsuitable, undesirable and diseased trees. This should be achieved gradually, bearing in mind that the aim is to have good poplars in the upper story, and subsidiary shade trees and shrubs in the intermediate story and underwood. During this period the development of the crown must also be watched, since loss of timber can be avoided by encouraging natural pruning of the trunk. The most important task at this stage is to ensure the perfect formation of the intermediate and understories, by pollarding willows and other troublesome trees and by cutting back stool shoots.

By about the tenth year, the poplars should be evenly distributed with full access to the light, their crowns strong and symmetrical, their stems (cleaned of all dead branches) already surrounded and protected by a limited number of subsidiary species. The intermediate story and underwood will ensure efficient soil protection and a regular supply of rain water to the soil.

Thinning and felling to ensure access to light

The object of thinning is to shape the stand according to the aim envisaged and, giving particular care to the best poplars, must above all preserve the composition of the different stories throughout the life of the stand and ensure efficient soil protection.

The horizontal closing of the canopy — or overlapping of crowns — constitutes a threat to poplar growing in the forest. Thinning should be carried out according to the principles of selective felling, that is, by selecting the best trees, opening them and stimulating the growth of the intermediate and understories. The poplars must be brought quickly into open growing conditions, so that 35 years later the final spacing is attained. If the crowns meet toward the end of the rotation, this is no longer a disadvantage; it may even be necessary in order to obtain the maximum yield and revenue.

Creation of new stands

By felling a stand a form of regeneration occurs. Natural regeneration of poplar is precluded by its genetical constitution and stands of poplar are, without exception, created by means of planting. The understory of shade trees must, on the contrary, be renewed naturally depending on the availability of suitable species and good growing conditions. Poplars should only be introduced artificially when the new copsewood has been opened up. At this stage, for a period of at least two years, the biological advantages of border trees can be put to account. If the conditions of the soil and the stand do not permit natural regeneration of the shade trees, the stand should be cleared by successive clear fellings and the gaps planted up with poplars. From the silvicultural point of view of the method of extraction and of protection, a sinuous felling face is preferable to a straight one, just as a short felling series is preferable to a long one. Felling of large areas at a time should be avoided. Contrary to common belief, it is essential so far as poplar is concerned to protect the felling area from sun, wind and storm, particularly in flood zones, where poplars are sometimes under water for months at a time. Winter flooding may cause serious damage to young poplars when frost follows quickly after a thaw and the waters bring down ice. In these conditions only poplar types suited to the site with an understory of willow pollards will survive.

Stands which are not worth tending or are unsuitable for conversion should be clear-felled and replaced with young stands, an operation which should be carried out in a small area at a time, beginning with the best soils and the poorest stands.

"*Surface types*" *and experimental exploitation of poplars in the forest*

Modern forest exploitation methods attempt to show as far as possible the purpose and the technique of the management practices they recommend. For this purpose "surface types" and sample plots are set up and exploitation tests carried out. This is the only way of determining productivity with accuracy, of making comparisons and forecasting results. Research and test plots are particularly valuable when entering new technical fields. This is the case, for example, with the change in the methods of exploitation required by alluvial forests, particularly with the introduction of poplar as the principal reference species.

The following have been selected from a large number of comparable stands, "surface types" and experimental exploitations:

1. "Surface type" Neuburgweier 1/14: area 1.8 hectares. Conversion of mixed coppice to high forest restocked with poplars after felling (Plot 1).
2. "Surface type" Rheinbischofsheim. Afforestation of unproductive marshland with hybrid poplars (Plot 2).
3. "Surface type" Neuburgweier, felling 13: area 1 hectare. Sample poplar stand in alluvial forest (Plot 3).
4. Experimental exploitation of poplars in alluvial forest. Communal forest of Neuburgweier, 40 hectares. Forest district of Karlsruhe (Plot 4).

SUBPLOT 1. – DEMONSTRATION PLOT, NEUBURGWEIER 1/14: AREA 1.8 HECTARES

Conversion of coppice with standards to high forest by felling the coppice and planting up with poplars (Plot 1)

(last coppice felling, 1915; site planted up with poplars, 1916)

Inventory

Volume (m³)		Cash value (DM)
280	1908	7000
605	1950	42000

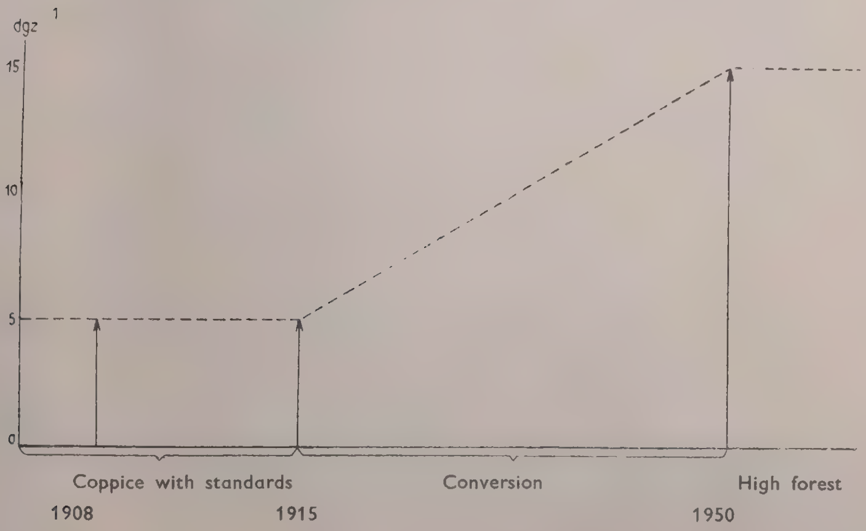
Increment 1908-50

Volume (m³)		Cash value (DM) [2]
681	Yield	27000
325	Increase in crop volume	35000
1006	Total yield	62000

Per annum, per hectare: 15 m³

Per annum, per hectare: 820 DM [2]

Increment increase 1908-50



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[1] Total average increment.
[2] 4.2 DM = $US 1.00.

SUBPLOT 2. – DEMONSTRATION PLOT, STATE FOREST OF RHEINBISCHOFSHEIM: AREA, 1 HECTARE

Permanent experimental plot of the Forest Administration of South Baden (Plot 2)

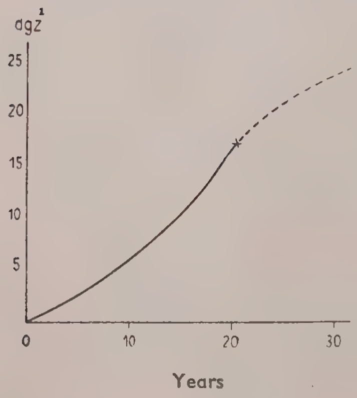
Improvement measures

Original site conditions	Unproductive marshland, reeds to a height of 2 meters, some willow pollards, some coppice shoots from alder stumps.
Improvement measures	Drainage system developed.
Stand composition	In 1932, 2-year-old poplars (planted on mounds or on banks).

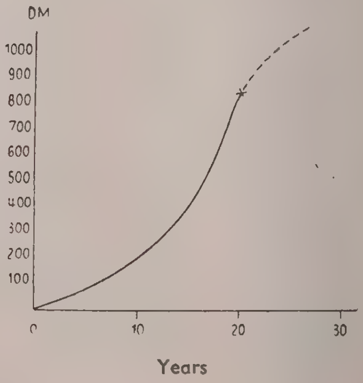
1952 evaluation

Volume (m^3)		**Revenue (DM)**
65	Intermediate yields	2300
286	Volume of standing timber	15 000
351	Total yield	17 300
Per annum: 17.5 m^3		Per annum: 865 DM

Annual volume production



Annual revenue (DM)



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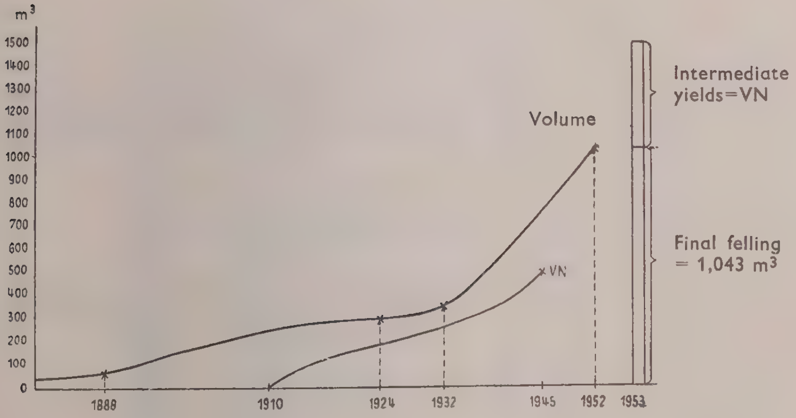
[1] Total average yield.

SUBPLOT 3. – DEMONSTRATION PLOT, NEUBURGWEIER FELLED AREA No. 13: AREA, 1 HECTARE

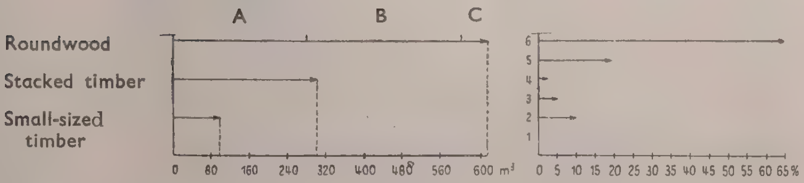
Experimental stand for the cultivation of poplar in alluvial forests (Plot 3)

History of the stand

Up to 1908, normal regime of coppice with standards; 1924, conversion started. From 1935, the stand consisted solely of poplars treated as open high forest; 1953, stand felled.



Diameter classes[1]



Yield from 1953	felling	1,043 m³	91,140.— DM
	per m³		87.38 "
Total yield 1888-1952		1,500 m³	120,000.— "
	per annum	23.4 m³	1,875.— "
	per m³		80.— "

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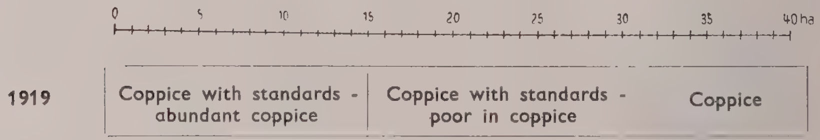
[1] Second class = 21-30 cm.; third class = 31-40 cm.; sixth class = > 60 cm.

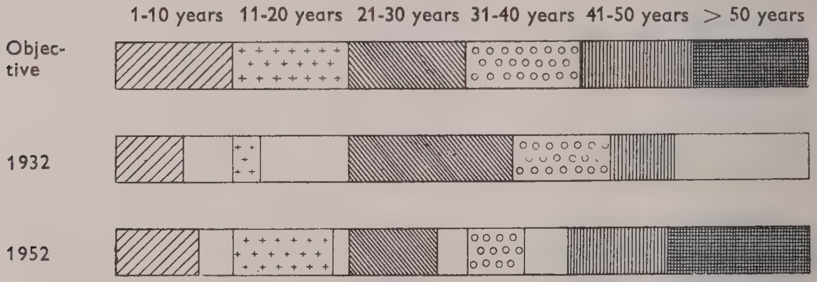
SUBPLOT 4. – COMMUNAL FOREST OF NEUBURGWEIER: AREA, 40 HECTARES

Demonstration felling of cultivated poplars in alluvial forests (Plot 4)

(up to 1925, regime as coppice with standards and simple coppice, followed by conversion to high forest)

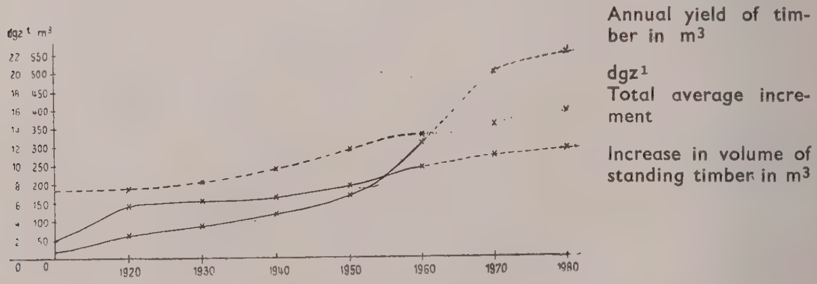

0
5
10
15
20
25
30
35
40 ha
1919
Coppice with standards - abundant coppice
Coppice with standards - poor in coppice
Coppice

Conversion stages

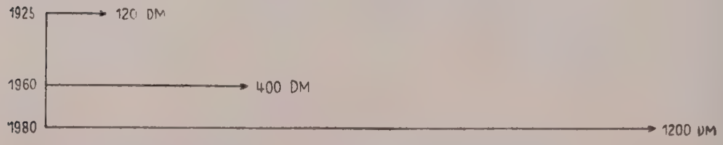


Result of conversion

Increase in the volume of standing timber and in the increment of the annual yield of timber.



Gross revenue per hectare



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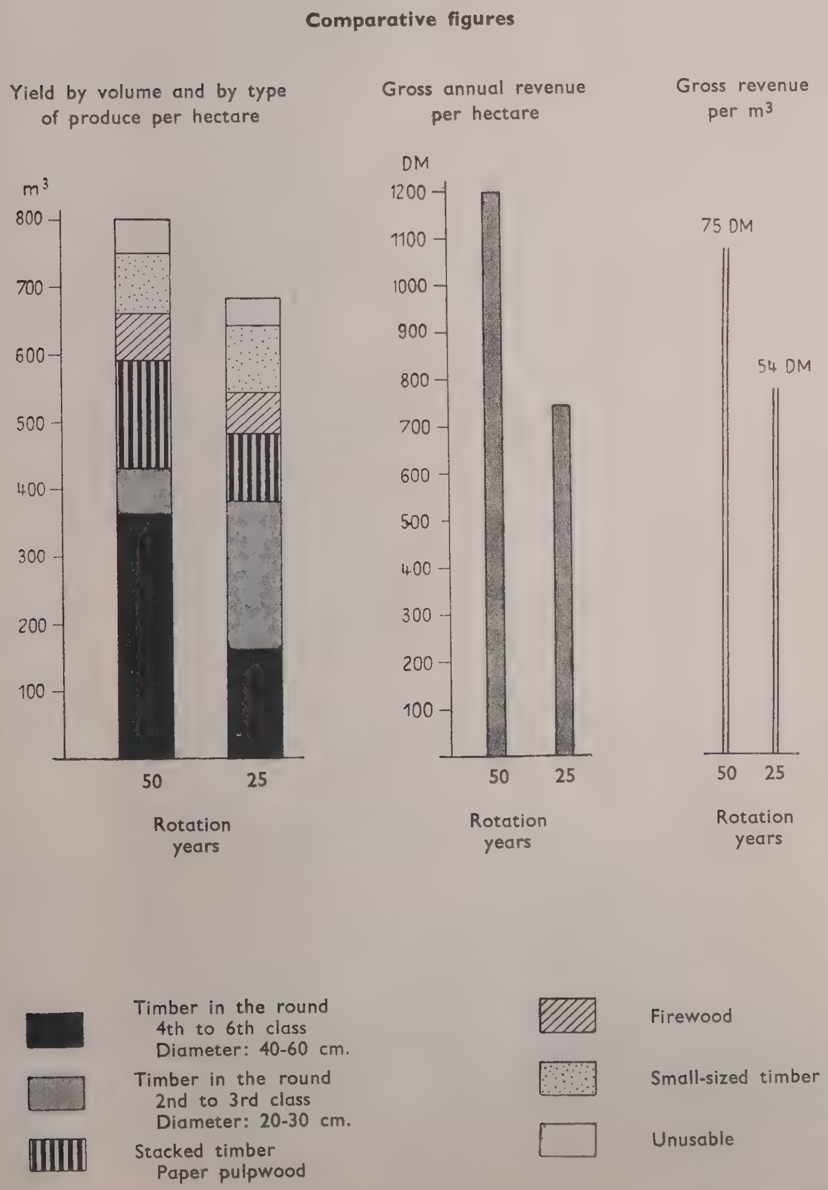
[1] Total average increment.

Subplot 5. – Usable classes of poplar on a rotation of 50 and 25 years (Plot 5)



Comparative figures

Yield by volume and by type of produce per hectare

Gross annual revenue per hectare

Gross revenue per m3

Experiments have been carried out in this forest with conversion techniques, using in particular hybrid poplars as the principal reference species.

The conversion of mixed coppice to high forest was started in 1925 and within 20 years a series of improvement fellings were carried out in the stand, with age groups ranging from 1 to 60 years. This was only made possible by the introduction of poplar as the principal reference species. The following silvicultural methods were employed:

- *a*) clear-felling unsatisfactory stands and establishing poplar as the principal species, starting with the best sites;
- *b*) improvement of coppice with standards and planting of poplar;
- *c*) conversion by planting up gaps with poplar;
- *d*) draining marshy areas and planting with poplar as the major species, and with an underwood of willow and alder a subsidiary species.

The table shows the yield from Plot 4, the conversion stages and its results:

- *i*) on the growth increment and hence on the volume of timber felled on a sustained yield basis;
- *ii*) on the increase in annual timber production;
- *iii*) on the annual increase in the gross yield in terms of revenue;
- *iv*) on the development of the standing timber.

This economic development and the extended cultivation of poplars shows the following increases over the old methods of exploiting coppice with standards (100 percent):

Annual felling on a sustained yield basis	approx.	300 %
Annual timber production on a sustained yield basis	,,	900 %
Gross annual receipts	,,	1,300 %
Volume of standing timber	,,	180 %
Communal investment in the forest	,,	400 %

Although the particular conditions of the timber market in Germany magnify the financial advantages of this method, there is, without doubt, scarcely any other forestry production program which offers such a chance of success. At a time when there is already a grave crisis in European timber supplies, the scheme for poplar growing in alluvial forests deserves serious consideration. The silvicultural achievements in the small communal forest described above, as well as elsewhere, for example, in the Drava Valley near Osijek in Yugoslavia, or in the Saône Valley in France, due to the extended use of poplars as the principal species, may serve as an example for thousands of hectares of alluvial forest land in Europe which are today still being treated extensively.

C. POPLAR GROWING IN NONALLUVIAL FORESTS

REASONS FOR CULTIVATION

The ever-increasing demand for softwoods makes it economically desirable to extend poplar growing outside its natural habitats — sites occupied by natural stands, alluvial forests, or wasteland suited to intensive poplar cultivation — particularly in areas where such sites are rare or are claimed by agriculture.

In central Europe, where soils have sometimes deteriorated and the biological balance has been destroyed by the widespread planting of pure conifers, the reintroduction of fast-growing broadleaved species such as poplar may be desirable both from the cultural and the economic points of view. Hence poplars are of primary silvicultural importance, tempered perhaps by biological considerations. A thorough study will therefore be made initially of the biological problems, with particular reference to forest sites suitable for the growing of poplar.

FOREST SITES SUITABLE FOR THE CULTIVATION OF POPLARS

Species of poplar cultivable in the forest

It should be remembered first of all that a species in a natural region may be absent from a particular forest association without being necessarily unsuited to the site conditions. Besides its ability to withstand competition from other vegetation, the biology of its reproduction is a decisive factor. Despite their rapid growth rate, poplars are relatively intolerant of competition due to the biological aspect of their reproduction and their need for light. Their natural reproduction depends on a set of conditions which are rarely found: the minute seeds which are extremely vulnerable to fungal diseases and liable to dry out, only germinate in full light on sites which are free of weeds and sufficiently moist for several months after germination. Similarly suckers of aspen and white poplar generally only thrive on open land. For this reason natural reproduction of poplars in the forest as a rule only occurs by chance, or after destruction by gales and forest fires. On the other hand, scattered examples often show remarkable vitality and conformity to site conditions.

Black poplar (*P. nigra*) grows in the valleys of the Swiss Alps up to a height of 1,300 to 1,440 meters (Lower Engadine) but is also found on the aeolian sands of Hungary. Even white poplar, although heat-demanding, manages to thrive at a height of 1,050 meters (Tessin, Valais). There is thus no doubt that particularly black poplar and its hybrids are of interest silviculturally well outside their normal forest associations.

Of all poplars, the aspens (*Populus tremula* and *P. tremuloides*) are adaptable to a wide range of ecological conditions and are virtually unaffected by the nature of the soil. In fact, they grow equally well on sandy or gravelly soils, which are poor and rather dry, as they do on heavy loam soils. Nevertheless, they only attain a good form and profitable size on sandy or clay soils which are fresh, friable, of at least average depth and sufficiently fertile. They are not affected by a variable water table and can tolerate temporary flooding; on the other hand, they avoid stagnant subsoil water and permanently marshy ground.

The lowland strains of *P. tremula* grow well in all the mixed broadleaved forests of central and western Europe, in oak-birch associations and in beech at low altitude. The European mountain strains are to be found particularly in the beech, fir and spruce forests throughout the length and breadth of the French Maritime Alps as far as the eastern Alps, and the mountain ranges in the Balkans, Asia Minor and the U.S.S.R. Similarly, the American aspen has a distribution which covers practically the whole of the continent. The great climatic and synecological tolerance of the aspens must not, however, make us forget the existence of innumerable ecotypes of varying silvicultural importance. But, generally speaking, few other species offer such wide silvicultural possibilities. All other species of poplar have distinctly narrower ecological, and particularly climatic, requirements. Moreover, the aspen is a typical "forest poplar," and on many sites fulfills an important function as a pioneer species, as well as occurring in mixture with other species. If up to the present time it has been of relative importance only in the forests of the U.S.S.R., northern and eastern Europe and North America, it will certainly increase in importance in the future in central and western Europe also, on account of its rapid growth rate, ecological adaptability and the rising value of its timber. Only the difficulties of propagation, already well known, hinder the extension of aspen cultivation; hence this matter will be examined in detail later on.

White poplar (*P. alba*) is much more heat-loving than aspen. It is distributed and planted above all in southerly regions, and is found chiefly on sandy soils in river valleys. Although it prefers fresh alluvial soils, it also thrives in regions of aeolian sand, for example in Hungary, on the shores of the Black Sea and the Mediterranean, and even on salty soils.

Its ecological tolerance is relatively poor, particularly as regards temperature. It is a typical poplar of alluvial forests, mainly because of the hot and arid climate of the principal regions in which it grows; outside these regions it is only rarely of silvicultural interest (on sand dunes, for example).

Gray poplars (*P.* x *canescens*), by reason of their hybrid origin, combine with extreme polymorphism ecological requirements which extend the full range between those of aspen and white poplar. They are mainly alluvial forest trees, with a very high timber yield, but are also satisfied with soils which are more acid, very compact or distinctly drier.

Black poplar (*Populus nigra*), and particularly its hybrids (*Populus* x *euramericana*) with the American species of black poplar, have much broader ecological requirements than those of white or gray poplar. By comparison with aspen, they are certainly more exacting as to heat and humidity and are definitely less adaptable to soil conditions. However, like aspen, they are of considerable silvicultural interest even outside the alluvial forest.

Certain balsam poplars, notably *P. candicans* and *P. trichocarpa*, appear capable of cultivation in the forest, although the results in Belgium, France and Great Britain are as yet too limited to make a definite recommendation.

The rest of this chapter is therefore concerned principally with aspen, gray poplar and the hybrid black poplars.

Comparison of the characteristics of "forest soils" and "poplar soils"

White aspen occurs naturally on a wide variety of sites; black poplar is virtually limited to the alluvial forest. From experience, it is claimed that *Euramerican hybrids* are remarkably productive even outside "*typical poplar sites.*" Moreover, in some cases the varieties and sites have not been selected with very great care. As a result, there have often been failures and this has given rise to a certain reserve regarding the forest cultivation of poplars. For this reason it is necessary to go more deeply into the soil requirements of hybrid black poplars.

The Swiss Forest Research Institute has compared soils from various "poplar sites" on the Swiss plateau with forest soils. The "poplar soils" consisted of calcareous soils from the shores of lakes in western Switzerland, similar soils from the area where the River Rhône flows into the Lake of Geneva and from an alluvial forest in the Aar. The forest soils consisted of clayey brown earth originating from loess in an oak-hornbeam forest near Basle, various types of brown earth originating partly from *Würm* moraine clay in an oak-hornbeam forest and partly from *Würm* colluvial clay in an ash-maple stand in the instruction forest of the Ecole polytechnique fédérale (Federal Polytechnic) near Zurich, and lastly, a compact forest soil of *Riss* moraine origin in Langenthal.

While a feature of moraine soils is their very high clay content, the loam soils originating from loess near Basle are composed chiefly of silt and typical "poplar soils," that is to say, silt and sand. These types contain appreciably fewer solid particles than true forest soils or clayey brown earth on loess, and are characterised by their low *apparent density* in the deep-lying strata (approximately 90 to 125 centimeters). This density varies in poplar soils between 1.12 and 1.15; on the other hand, it is as much as 1.65 to 1.73 on the *Riss* moraine, 1.52 to 1.57 on the *Würm* moraine and the top 30 centimeters of loam originating from loess, reaching 1.50 in the principal root area.

Analysis showed the *over-all porosity* of poplar soils to be greater in all horizons than that of the forest soils examined. Everywhere it exceeded 500 cubic centimeters to the liter, whereas even in friable, biologically active forest soils, the pores rarely occupied more than 500 cubic centimeters and often fell below 400 cubic centimeters at a depth of only 60 centimeters.

The *size of the pores* differs also. On all the "poplar soils" an average of 215 cubic centimeters of large pores, 216 cubic centimeters of medium pores and 86 cubic centimeters of fine pores have been measured per liter of natural soil. The figures for loess clay are respectively 2.8 times more, 0.9 times less and 0.8 times less. *Poplar soils contain a relatively large number of large pores and few small pores.*

Poplar soils have a relatively low *humus* content but usually a good *proportion of carbonates*; this was noticeable in all horizons. The pH *reaction* varied between 6.2 and 7.5 with an average pH of 6.8.

Diagrams 2 to 8 give further details.

DIAGRAM 2. – SIZE OF PORES AND SOLID PARTICLES OF A "POPLAR SOIL"

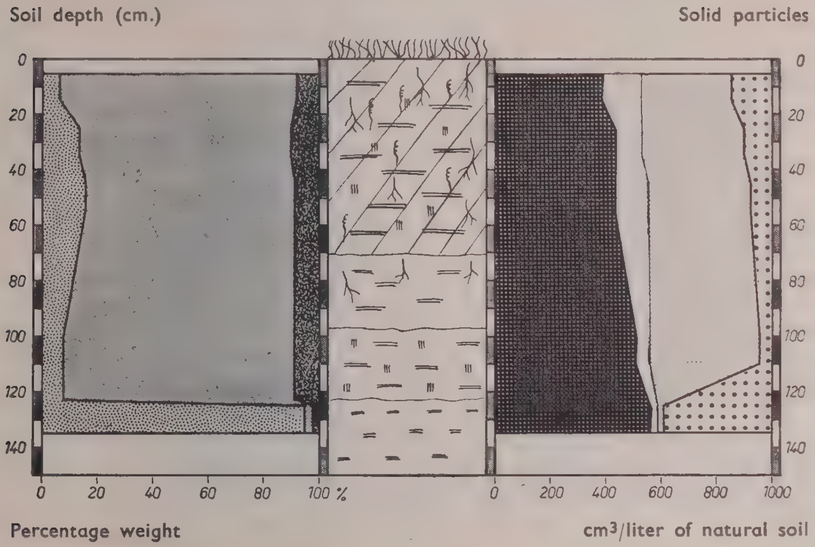

Soil depth (cm.)
Solid particles
0
20
40
60
80
100
120
140
0
20
40
60
80
100 %
0
200
400
600
800
1000
Percentage weight
cm3/liter of natural soil

DIAGRAM 3. – SIZE OF PORES AND SOLID PARTICLES OF A LOAMY BROWN EARTH ORIGINATING FROM LOESS UNDER AN OAK-HORNBEAM FOREST (ALLSCHWIL)

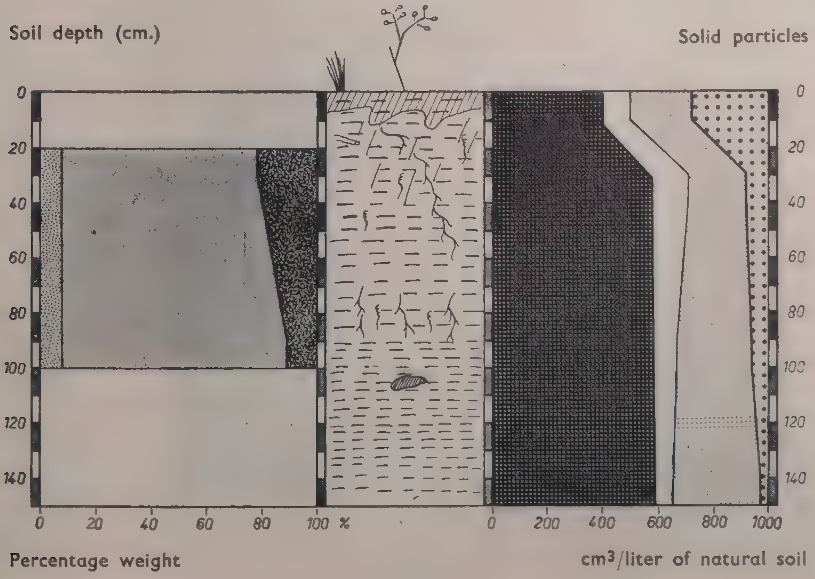

Soil depth (cm.)
Solid particles
0
20
40
60
80
100
120
140
0
20
40
60
80
100 %
0
200
400
600
800
1000
Percentage weight
cm3/liter of natural soil

DIAGRAM 4. – SIZE OF THE PORES AND SOLID PARTICLES OF A BROWN EARTH ORIGINATING FROM A CLAY MORAINE OF "WÜRM" UNDER AN OAK-HORNBEAM FOREST (INSTRUCTION FOREST OF THE ECOLE POLYTECHNIQUE FÉDÉRALE)

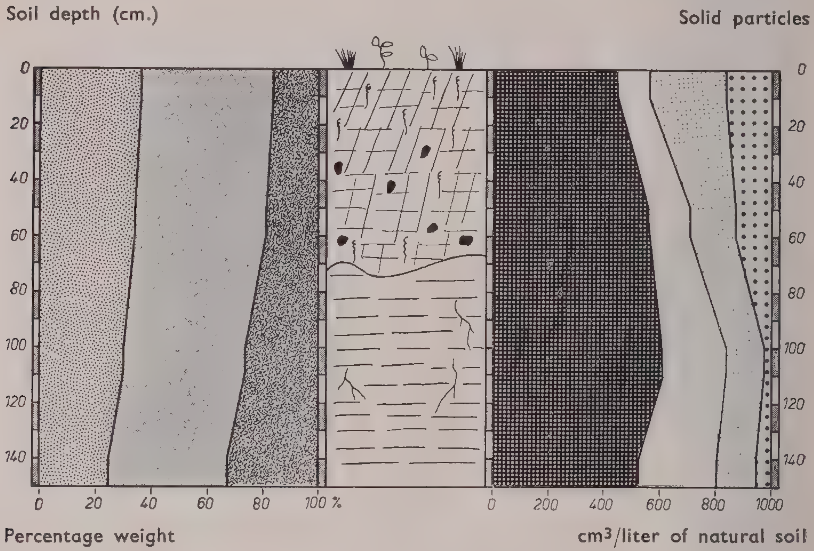


DIAGRAM 5. – SIZE OF PORES AND SOLID PARTICLES OF A BROWN EARTH ORIGINATING FROM "WÜRM" COLLUVIAL CLAY IN AN ASH-MAPLE FOREST (INSTRUCTION FOREST OF THE ECOLE POLYTECHNIQUE FÉDÉRALE)

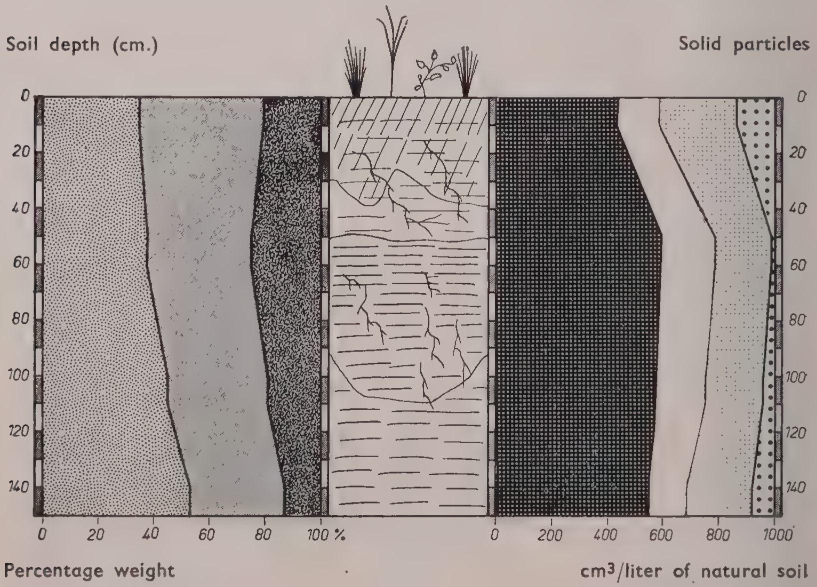
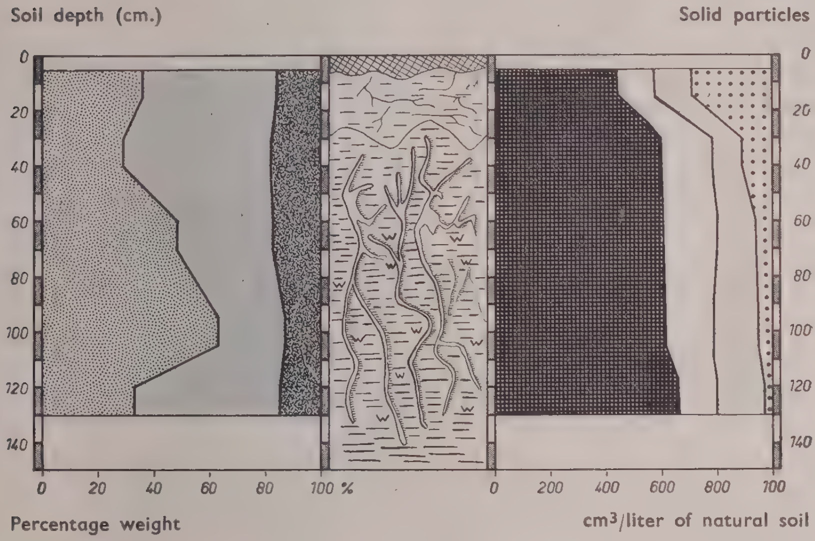


DIAGRAM 6. – SIZE OF PORES AND SOLID PARTICLES OF A COMPACT FOREST SOIL OF "RISS" MORAINE ORIGIN (KÜHSTELLI)



░ sand

☐ silt

▒ clay

■ solid particles

☐ small pores

☐ medium pores

⁙ large pores

≋ litter

▨ mull

▩ more

∫ activity of earthworms

= calcareous sand

≡ calcareous clay and silt

≈ calcareous concretions

Ψ roots

○ stones ∅ > 2 mm.

∼ level of water table

w water flow

‖ gley concretion

Typical poplar soils therefore contain a certain proportion of carbonates, their structure ensures gaseous exchange and a regular water regime, their apparent density is low, with a high degree of porosity to a depth of at least 60 centimeters. Outside these ideal conditions *clones should be selected with caution on the basis of tests and, if possible, on experience obtained from old, existing plantings.* On heavy, compact and badly aerated soils, the number of suitable types will be very small. Moreover, ecological tolerance decreases considerably at an altitude of over 600 meters, and over 700 meters it is not advisable to introduce poplar into the forest on account of snow patches, although individual hybrid black poplars do flourish even above 1,000 meters.

The different forest associations suitable for poplar cultivation

The description below is limited to the broadleaved forests of western and central Europe and the plains just south of the Alps. In more southerly regions the dry climate precludes poplar growing except on alluvial soil. The Alpine region proper and the forests of north and northeast Europe will only be mentioned in connection with aspen.

These examples permit ready comparison with similar forest regions. The alluvial forest type has already been dealt with.

Owing to the appearance of chestnut blight in the *subalpine-oak-elm-chestnut forests* (*Castanea vesca*) it has been necessary to introduce urgently a fast-growing species of economic value. Aspen, the only indigenous poplar of the region, is found for the most part only as individual trees of poor form. The success of hybrid black poplars on these poor, acid soils still appears doubtful. On the other hand, experiments have shown that aspen and its hybrids, particularly gray poplar, can be recommended unreservedly. As for the *oak-elm plantations* of western Europe and the coastal oak forests of the Atlantic, remarkable results have been obtained with hybrid poplars, especially in Belgium.

The region of the *mixed broadleaved mesophytic forest*, with its variety of forest associations, is that most suited for the cultivation of hybrid black poplars, and aspen and its hybrids. It includes a variety of forest conditions with soils ranging from those moist and clayey to others dry or highly leached. However, moist soils, loams and only slightly permeable soils predominate. *Aspen* and its hybrids find suitable ecological conditions everywhere, and while more frequent on dry sites, they nevertheless attain the best increment and habit on the moist sites of oak-hornbeam forests. In the Paris basin certain gray poplar clones have also

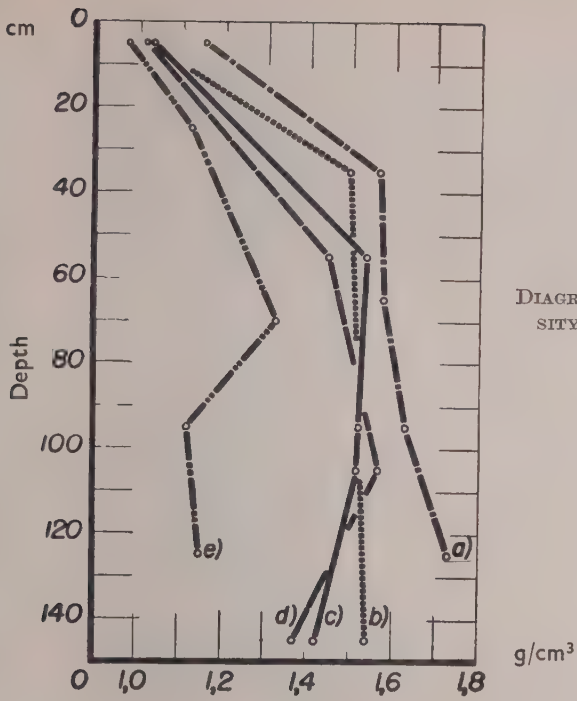


DIAGRAM 7. – APPARENT DENSITY OF FIVE SOIL TYPES

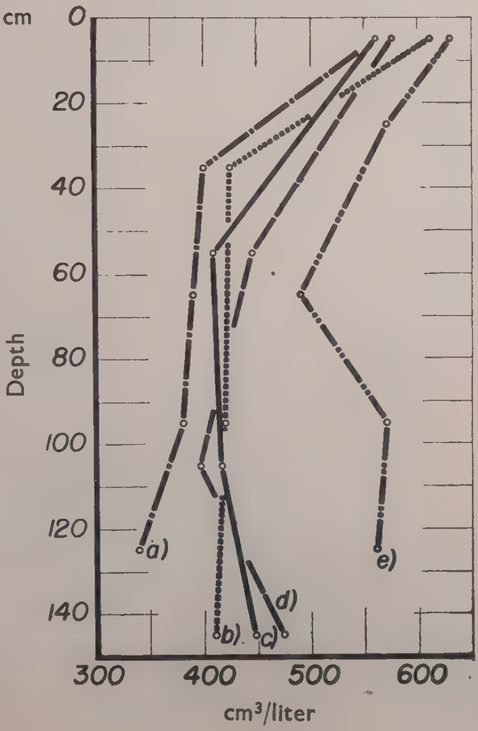


DIAGRAM 8. – POROSITY OF FIVE SOIL TYPES

a) *Riss* moraine

b) Brown earth on clay of loess origin in an oak-hornbeam forest

c) Brown earth originating from *Würm* colluvial clay in an ash-maple forest

d) Brown earth originating from *Würm* morainic clay in an oak-hornbeam forest

e) " Poplar soil "

given excellent results for the past 150 years. The soils of oak-hornbeam forests, which are on the whole heavy but virtually neutral, fertile, relatively well aerated, fairly moist throughout the year, and biologically active, and with a mesophytic underwood, provide one of the best sites for hybrid black poplars. While very heavy soils should be avoided, experience has shown that all other soil types are highly suitable for poplar cultivation and are, in fact, closely allied to conditions in the alluvial forest.

Beech forests contain innumerable forest associations with widely varying soil and climatic requirements. Although all such sites are suitable for aspen, it is in fact frequently absent from them on account of competition from other species. Aspen can play a useful part both economically and silviculturally on comparatively dry soils, provided they are rich in fine earth. The fairly moist and rich soils of beech forests at low and medium altitudes appear suitable for *hybrid black poplars*. In spite of good growth results in the dry beech forests of Baden, there is no information available of the experience over a long period in extensive areas.

Only aspen is of interest in beech-fir stands and in certain associations of the typical fir forest. It is of economic importance especially in the spruce forests of the north and in the central Alps, and in both of these areas good quality strains of sound habit are to be found.

These few examples will show that poplar growing can be developed considerably, even outside the alluvial forest. However, apart from the cultivation of aspen in the *Scandinavian countries*, the possibilities have been almost completely neglected; that is to say, the groups which exist in many forests have been planted on a trial basis and do not provide precise data. Moreover, the preliminary work of selection and practical experimentation have not been carried out, and a closer connection between practice and theory would therefore appear essential.

METHODS OF POPLAR CULTIVATION IN THE FOREST

Natural regeneration, artificial propagation and treatment of aspen and its hybrids and of gray poplar

Natural regeneration of aspen [1]

The regeneration of poplars naturally is applicable only to aspen, and a clear distinction should be made between seeding and suckering.

For the *natural seeding of aspen* the requirements are wasteland, giving suitable conditions of light and a satisfactory degree of moist throughout the germination and seedling stages. Seeding also depends on the phyto-pathological factors and very dense regeneration is often found on burned sites where aspen readily forms a pure pioneer forest, invaded later by other species such as spruce or sometimes even pine. Forest fires are thus the origin of many large aspen stands both in Europe and in America. Without them, natural aspen regeneration is uncertain and casual. Systematic land clearance is only feasible in coniferous forests and, because of the protective measures required, on flat ground. It is, in fact, only practiced on a large scale in north and northeast Europe and in North America as a result of the extraction methods used in these regions.

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[1] Applies to both America and Europe.

In broadleaved forests, aspen multiplies almost solely by suckering; that is, by means of suckers or leafy shoots which sprout from adventitious buds on the roots. Suckering capacity is very highly developed in aspens, and slightly less so in white and gray poplars. An aspen of medium age is capable of putting out suckers over an area of more than 1,000 square meters but as a rule such vigorous suckering is considered a nuisance. In spite of their very fast initial growth rate, little use is made of suckers, as the dying roots of the mother trees very often transmit fungal diseases which are frequently the cause of trunk rot. It would be a mistake, nevertheless, to reject in principle the use of suckers, as they have been known to produce good, healthy, fast-growing stands. However, a disadvantage of natural regeneration is that it does not allow the use of selected trees capable of increasing production.

Artificial propagation of aspen and its hybrids

Aspen, and white and gray poplars, unlike other poplars, do not root from woody shoots, or if they do, it is only slightly. Propagation by root cuttings is, of course, possible but it is inconvenient and has the same disadvantages as with suckers. While the use of growth hormones improves the rooting ability of woody shoots, it does not guarantee success and has not yet proved economic. Reproduction from seeds, on the other hand, is far more simple, as has been shown in another section of this chapter.

Healthy and vigorous 2-to-3-year-old plants should be planted for preference, if possible in a soil pot or at least with good roots, as aspen and its hybrids are markedly affected by faulty planting and, if growth is arrested, are vigorously attacked by the small poplar longhorn beetle. To avoid rotting of the roots, damaged roots should be removed with a sharp knife. Gray poplars and hybrid black poplars are planted at the same spacing. which varies between 3 to 4 meters, according to the mixture.

Aspen can be cultivated as well in pure stands as in a mixture with other species which are similar to it biologically, such as alder (*Alnus glutinosa*), cherry (*Prunus avium*), ash (*Fraxinus excelsior*) and birch. The raising of these species to approximately the same felling age, generally between 50 and 60 years, is easily facilitated by rigorous systematic thinnings. A mixture with alder is exceptionally well suited to fresh broadleaved forest sites. For example, in Switzerland, in the instruction forest of the Ecole polytechnique fédérale, an excellent 30-year-old mixed stand of aspen, alder and ash has a standing timber volume of 232 cubic meters per hectare, with a current increment of 11.2 cubic meters.

Carefully constituted intermediate and understories play an essential part in aspen cultivation. The most satisfactory species are, according to site conditions, hornbeam (*Carpinus betulus*), small-leaved lime (*Tilia parvifolia*), field maple (*Acer campestris*), bird cherry (*Prunus padus*), beech (*Fagus silvatica*), black cherry (*Prunus serotina*) and many shrubs. A secondary stand as mixed as possible, in order to stimulate the biological activity of the soil, is of primary importance for aspen. Medium-sized trees are best suited for this purpose; they carry out their function even during the second half of the life of the aspen without hindering crown development.

In Scandinavian countries spruce generally becomes established under aspen and at first fulfills its function as a secondary species very well. However, at an age of about 30, it catches up with the aspen, at about 50 equals or outgrows it and rapidly causes its elimination (*see* Diagram 9).

Deprived of light, root suckers sprout and are generally attacked by root fungi which multiply with ease in the main stand. Their growth can be prevented if the understory is dense.

Good treatment of aspen from an early age will ensure that its growth is not hindered. Slow growth generally lays the tree open to serious attack by the small poplar longhorn beetle, or to fungal diseases, and encourages irremediable phototropic distortion of the trunk and loss of increment. *Thinning*, that is, the selection and opening up of the best stems, should begin very early. Cleaning is restricted to balancing the mixture of species in the upper and intermediate stories. At the age of 8 or 10 years, at the latest, the growth conditions should be such that good specimens of aspen can reach the age of 30 with a productive crown covering half the trunk. Up to the ago of 40 or 50, the crown should

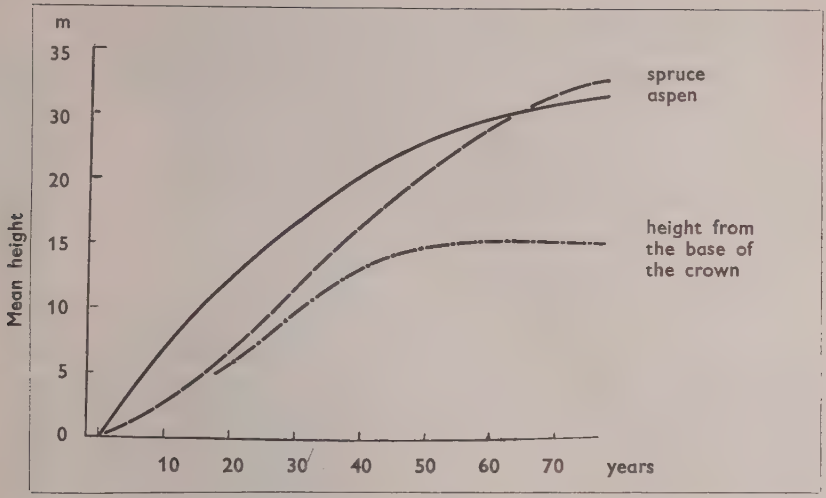


DIAGRAM 9. – HEIGHT INCREMENT OF SPRUCE AND ASPEN OF EQUAL AGE ON OPTIMUM SITES, SHOWN DIAGRAMMATICALLY

only be one third of the total height. On good sites the process of opening the stand can be started between the ages of 35 and 40 years, so as to maintain vigorous crowns at a constant height. Further reduction of the crown does not increase the proportion of timber but, on the contrary, appreciably diminishes the increment.

The dry branches of aspen do not decompose well; stubs and scar swellings, moreover, cause serious defects in the wood. It is therefore advisable to prune dry branches with care. Pruning is begun immediately the stems attain a diameter of 8 to 10 centimeters and is carried out with a fine-toothed saw. In two or three operations all the dry branches are removed up to a height of 8 meters and up to 12 meters on the best stems. The same technique is applied to the spruce.

The treatment of aspen is equally applicable to its *hybrids and gray poplar.* In many forests damage by game at present makes protection necessary and prevents really economic cultivation. In fact, aspen and its hybrids are browsed throughout the year, and during the growing season goats rub against them in preference to other trees. Only trellis enclosures and individual protection as applied to other species (particularly netting sleeves) have proved effective.

Cultivation of hybrid black poplars in the forest

The success of poplar cultivation in the forest is based on the following four principles:

1. selection of good clones;
2. cultivation on suitable sites;
3. good silvicultural practices;
4. methodical treatment.

The importance of clonal selection has already been emphasized. Among the clones best suited to the site and the desired technical requirements, preference should be given to those having a narrow crown and the least phototropic. The soundest choice is based on local experience over a long period. Unfortunately, there is generally very little information available on the cultivation of poplar in the forest. The transposition of experience obtained elsewhere requires particular care and should be limited to small areas and comparable sites. The results of short-term experiments on cultivation should also be interpreted with reserve, since premature generalization is dangerous. Foresters tend to accept the results as proved and hence restrict cultivation to a few clones. *A species can be considered as suitable to a particular site and technically satisfactory only after it has behaved well on the site for at least one generation of trees.* This is one of the principal arguments against the planting of a single clone on the site; moreover, in the interests of forest protection a mixture of clones is advisable. As it is not usually possible to obtain a sufficient number of clones which have been tested over a long period on forest sites, it is advisable to make a selection based on preliminary short-term tests which contain at least four or five clones apparently suited to the environment. The first "thinnings" will eliminate the least suitable clones. With increase in age, the number of clones is thus reduced but the disadvantages and dangers are lessened, inasmuch as the surviving clones will have proved their superiority.

To ensure the success of poplar cultivation in the forest, special knowledge, and experience on *site evaluation* and clone selection are required. Local foresters who do not possess these qualifications should consult a poplar expert versed in soil science, phyto-sociology and in the ecology of the clones which may be suitable. In practice, an expert is usually called in too late, when all he can do is confirm that the plantation has failed and at best explain why this should have happened.

When hybrid poplars are used in the forest two fundamentally different aspects should be distinguished: the cultivation adapted to particular forest conditions, and the silvicultural techniques adapted to the project of poplar cultivation. The ecological and silvicultural conditions will determine which of these alternatives applies.

It is generally accepted that opportunities for the forest planting of poplar are rare but they are becoming more frequent, as will be shown.

The use of poplars for planting up gaps is only likely to be successful in well-defined conditions. Poplars cannot tolerate any lateral shade; deprived of direct light for more than a third of the day they develop phototropic distortion and their height growth slows down appreciably. On suitable sites they grow admirably in regeneration gaps, provided that they are at least the same size as the surrounding trees at the time of planting and are capable of outgrowing them in a few years. In older stands, they require a rather large growing space — 500 to 1,000 square meters, depending on the height of the surrounding trees, the degree of exposure and the slope. From the beginning, moreover, their high light and space requirements and average felling age should be taken into account. In fact, if the silvicultural plan of operations and the treatment of the rest of the stand do not take this into account, the felling of the poplars at a time before the other species is difficult and presents a serious silvicultural problem.

When planting *poplars on the edge of forests or along forest roads*, phototropic distortion due to unilateral shade should at all costs be avoided. Poplars can nevertheless render valuable service to the forester by protecting the borders of forests against sun and wind and by enclosing large regeneration areas, etc.

Finally, there is often the opportunity to *plant poplars on sites where emergency fellings* have been carried out, as no other species provides such speedy stocking and compensation for loss in increment. For this purpose, the same basic technique applies as for *cultivation over wide forest areas*. Above all, it is important to select a good mixture. On large bare areas the species will be mixed by stories, poplars constituting the dominant story, with hornbeam, lime, bird cherry, beech, sycamore, etc. in the intermediate and understories, depending on the site conditions. In any case, an effort should be made to establish a secondary stand as far as possible by stories and which may, in exceptional cases, even include spruce on fairly fresh, biologically active and fertile soils. On the other hand, in cases where poplar can supplement extensive existing regeneration it is quite feasible, and even advisable, to include in the future dominant story other fast-growing species such as ash, birch, cherry, etc. In all cases, a secondary stand which is well mixed and has the proper stories, is indispensable and requires the same treatment given to the dominant story.

The treatment of poplar in the forest differs from that of all other species. As selected clones are used, they can generally be relied upon to produce good hereditary characteristics. Furthermore, selection thinning is confined to the elimination of unsuitable clones or stems damaged in one way or another. Treatment will aim at protecting the trees from damage, assisting the formation of trunks free from knots, and ensuring a sufficient amount of light to prevent phototropic curvature. In the forest, the *young poplar* is exceptionally liable to damage by game animals and a variety of rodents. Damage may be avoided by applying the measures described in the chapter on insect and animal pests.

The pruning and opening up (*thinning*) *of poplar plantations* are performed in the same way in the forest as outside it. However, the way in which these stands are often scattered over a wide area makes the essential operations more difficult to carry out, especially as great care is necessary in their execution. Which modes of treatment are best suited to poplar? The question is of secondary importance, since all techniques with the exception of the traditional selection felling are applicable. Poplars can be planted in regeneration areas beneath the canopy, on the edges of forests or in groups in high forest. This is, in fact, of small significance compared with the vital importance of the factors dealt with above, such as the choice of sites and clones, the thinnings required to ensure sufficient light, the protection against game animals and judicious pruning and manuring, etc. The best way to counter the changing ecological and silvicultural conditions is to adopt a technique which is elastic and free from any hard and fast rule. The application of sound silvicultural principles which are valid for all other species will also contribute to the success of poplar cultivation in the forest.

ANIMAL PESTS AND DISEASES

During the second half of the nineteenth century there was a tendency in some countries to replace mixed plantations by pure stands, more often than not even-aged. Such action, which was prompted by economic considerations, was not always justified by results. In fact, pure stands, and more especially even-aged stands, are highly susceptible to damage by wind, snow and frost; they also exhaust the fertility of the soil and, more important still, are particularly vulnerable to attack by pathogenic agents.

The above remarks do not, of course, all apply to poplars, which are not for the most part grown as a true forest species but are cultivated by intensive methods, that is to say, manured and carefully tended. However, it should not be forgotten that poplars are also grown today in even-aged stands consisting sometimes of a single clone. If such stands are attacked by pathogenic agents, the results are necessarily disastrous for the following reasons: *a*) a *pure* stand offers ideal conditions for the attack to reach epidemic proportions, as infection is spread directly and rapidly from one tree to another; *b*) it frequently happens that parasites are virulent at one particular stage in the growth of the tree, and hence *even-aged* stands are the most vulnerable; *c*) the reactions of trees to attacks by diseases and insects do not vary in the case of a stand *composed of a single clone*, and hence, if the clone is not resistant, the entire stand is destroyed.

These facts are not intended in any way to discourage poplar growers but merely to draw their attention to the risks involved in the cultivation of the species; risks which are, however, amply justified by the direct and indirect advantages which can be obtained. It is only by being fully aware of the risks that the forester can take the necessary steps to limit their consequences and, fortunately, he has at his disposal several means of reducing the hazards of poplar cultivation. He should, above all, observe the principles described in Chapter II, " Poplar Cultivation, " both for propagation and for actual cultivation, in order to raise vigorous trees and hence less prone to attack. In view of their importance, these principles are briefly restated here: choose the site with care and plant the poplar types (of recognized identity and origin) best suited to it; raise the plants by sound methods; adopt good planting practices with particular attention to spacing; tend the trees carefully after planting (by weeding, thinning, draining, etc.); protect the trees from all damage and, if necessary, grow poplars in mixture with other species to improve the soil. Lastly, the planting of disease-resistant types as well as direct anti-parasite measures, now offer great opportunities for successful cultivation.

Since its creation in 1947, the International Poplar Commission has devoted considerable attention to the hazards of highly intensive poplar growing, and the question of the parasites which attack poplars has been thoroughly discussed at each of the eight sessions held by the Commission to date. The Commission's activities in this field have taken two forms. First, it has requested national poplar commissions to undertake an investigation into the insects and diseases causing damage to poplars in member countries; and in order to assemble as complete and comparable a documentation as possible, it has prepared a questionnaire on the degree of resistance of different poplar types to the various parasites and also to inorganic agencies such as wind, snow, frost, etc.

The Commission's second contribution to this question has been to study the most effective means of preventing the transmission of poplar parasites and diseases from one country to another. At its very first session, the Commission expressed anxiety at the serious danger of the spread of poplar parasites with the exchange of planting stock. As there was no question of discontinuing exchanges, the Commission appointed a working group to study the question as a whole and to propose control measures. The Commission subsequently approved the report of this working group and submitted it to the national commissions for their consideration with a view to applying the measures recommended (*see* Appendix 1).

The two sections which follow contain a study of animal pests and diseases affecting poplars and the control measures most commonly used to combat them.

I. ANIMAL PESTS INJURIOUS TO POPLARS

There are many animals, and particularly insects, which attack poplars, and it is necessary to distinguish between those for whom the wood or the foliage constitutes an essential source of food, and the casual ravagers, as for example many types of caterpillars, whose attacks may sometimes be dangerous but are always sporadic.

In all countries, the most serious pests are undoubtedly the xylophagous (wood-eating) insects, which bore deep tunnels into trees of all ages, facilitate the entry of micro-organisms and lower or even completely destroy the commercial value of the wood. Some of these constitute a formidable plague, against which the forester is often defenseless, and which are a permanent threat to the future of poplar cultivation in many countries.

The insidious role of sucking insects (cicadas, aphids, coccids) is no less negligible. By penetrating deep into the tissues with their rostrum to suck up sap, they weaken the tree and may inject into it harmful substances or bacteria. Research in this field, although still limited, should contribute to current knowledge on the development of certain diseases, such as the deadly weeping canker, whose scientific place is still somewhat obscure. It is known, on the other hand, that due to their remarkable reproductive capacity, certain species such as the woolly poplar aphis (*Phloeomyzus*) are capable of destroying large trees.

Damage by larger animals, such as rodents, game or even cattle, has long been of concern to poplar growers and foresters, and trees must be protected against them either by direct or indirect means.

Suffice it to say that many of the pests mentioned are extremely dangerous and their generally very wide distribution area makes them of common concern to many countries. Hence an essential step toward more effective control measures is to be able to distinguish between the various pests and to be familiar with the details of their biology.

Damage by insects and mites, on the one hand, and by rodents, game and livestock, on the other, is discussed in the two separate sections which follow. The information deals chiefly with the methods of control and distribution of the more important animal and insect pests. Details of indications of damage and the distribution area of the chief pests affecting poplars are summarized in the following two tables.

A. Insects and mites

Control measures against insects and mites

The control methods available are chiefly chemical and biological.

Chemical control

Recent progress in the field of phytopharmacy, notably since the discovery of insecticidal properties in synthesized organic compounds, offers much scope for the destruction of harmful insects and mites both in the soil as well as on the trunks or foliage of trees. Besides arsenic

TABLE 9. – EXTERNAL EVIDENCE OF ATTACK BY THE PRINCIPAL ANIMAL PESTS OF POPLAR

Name of insect or animal pest	Part of tree affected	Description of damage	Injurious stage of insect's life cycle
Melolontha and *Phyllophaga*	Roots Leaves	Bark of roots and cuttings gnawed Leaves nibbled	Larva (white grub) living in ground Adults (cockchafers)
Capnodis	Roots and base of trunk	Sinuous galleries beneath bark (frass)	White legless larvae
Compsidia populnea	2-year-old stems and branches	Swelling with horse-shoe scar	Larva in gallery
Saperda carcharias *Saperda calcarata*	Wood of the lower part of the trunk	Deep galleries with ejection of frass	Larva in gallery
Agrilus	Stems and branches	Sinuous galleries beneath bark	Larva
Cryptorrhynchus lapathi	Stems of young trees	Canker-like distortion and frass	Larva and adult insect (black and white)
Sesiidae	Young stems and shoots Base of the trunk	Swellings Deep galleries	Larvae
Cossus	Trunks	Deep galleries with frass and odorous excreta	Very large purplish-red caterpillar
Agromyzidae	Narrow galleries in the cambium	Brown scarrings	Larvae very small, hardly visible
Cimbex	Shoots or stems	Horizontal scar with swelling	Adult rarely seen

TABLE 9. – EXTERNAL EVIDENCE OF ATTACK BY THE PRINCIPAL ANIMAL PESTS OF POPLAR (*concluded*)

Name of insect or animal pest	Part of tree affected	Description of damage	Injurious stage of insect's life cycle
Rhynchites	Leaves	Leaves rolled into " cigars "	Weevils and small larva
Phytophagous *Curculionidae*	Leaves	Leaves margins nibbled	Weevils
Chrysomelidae	Leaves	Leaves completely ravaged	Bright-colored adults Small larvae in colonies
Phytophagous *Lepidoptera*	Leaves	Leaves completely ravaged	Various types of caterpillar
Semasia	Buds	Malformation in the form of double leaders	Larva rarely seen (excreta)
Tenthredinidae	Leaves	Leaves completely destroyed	Larvae (false caterpillars) in colonies and which lift the fronts of their bodies when disturbed)
Gall wasps or gall midges	Leaves, petioles and stems	Various types of malformation	Aphis or midges rarely seen
Cicadina	Shoots	Wood pierced, causing exudation of sap	Larva covered with spit
Phloeomyzus passerinii	Trunks	Trees killed	White woolly aphis
Aphididae	Shoots	Bark punctured and split	Aphis often detected by the presence of ants
Coccidae	Stems and trunks	Bark covered by the coccids, becoming rough	Scaly shields
Beavers	Trunks	Trees barked and felled	
Other rodents	Young stems	Trees barked at the base	
Cervidae	Bark	Bark nibbled intermittently	

TABLE 10. – DISTRIBUTION OF THE PRINCIPAL ANIMAL AND INSECT PESTS

Name of insect or animal pest	Europe	Near East	Far East	North America
Melolonthinae	*Melolontha melolontha* very widespread *Melolontha hippocastani* in central Europe			*Phyllophaga* Frequent
Capnodis		Very serious in Israel, Syria, etc.		
Compsidia	Very numerous			
Semasia	Frequent and fairly harmful			
Cryptorrhynchus	Frequent and dangerous			
Sesiidae	Numerous and dangerous			
Saperda	*Saperda carcharias* Very dangerous and numerous		*S. carcharias* Found as far east as Korea	
Cossus and *Zeuzera*	Very frequent and dangerous	*Cossus terebra* Very dangerous		
Cimbex	Frequent but generally not serious			
Agrilus	Frequent			
Agromyzidae	Frequent and fairly harmful			Fairly frequent
Spinners				

TABLE 10. - DISTRIBUTION OF THE PRINCIPAL ANIMAL AND INSECT PESTS (*concluded*)

Name of insect or animal pest	Europe	Near East	Far East	North America
Curculionidae	Frequent in nurseries but not particularly harmful			
Chrysomelidae	Very frequent, harmful in nurseries			*Phytodecta americana* Harmful
Phytophagous *Lepidoptera*	Numerous and fairly serious			Numerous and fairly serious
Tenthredinidae	Frequent but not very serious			Numerous and fairly serious in Canada
Rhynchites	Frequent but not very serious			
Leaf miners	Frequent but not dangerous			
Gall wasps or gall midges	Frequent on *P. nigra* but not dangerous	Frequent but not very dangerous		
Cicadidae	Frequent and fairly harmful			
Aphididae	Frequent but not very dangerous			
Phloeomyzus	Very dangerous in Italy	Found in Egypt		
Coccidae	Frequent and fairly harmful			
Beavers	Occasional damage in France			Fairly serious damage
Other rodents	Frequent damage			
Cervidae	Damage in Germany and Yugoslavia			Damage in Canada

compounds and organic products of plant origin such as nicotine, rotenone and tephrosin, which have long been used and are still of value, a whole range of special products is now on the market, the efficiency of which depends solely on their application at the right time. Their action is by direct contact, absorption and sometimes also by the emission of a toxic gas. The best known are dichloro-diphenyltrichlorethane (DDT or zeidane), hexachlorocyclo-hexane (BHC, lindane, gammexane) and its sulfur derivatives which form the base of many proprietary products; chlordane, toxaphene, aldrin, dieldrin, organic phosphates or phosphoric esters such as parathion. Systemic or teletoxic insecticides which have the action of drugs are also available; these are absorbed by the plant tissues, conveyed by the sap and hence poison the insects and mites which suck it. It should be emphasized that these new products need very careful handling, as many of them have a very high degree of toxicity for human beings, vertebrates, predatory and parasitic insects, and some are also injurious to cultivated plants. They should, therefore, be used judiciously with all the necessary precautions and in conformity with the following recommendations of the International Union for the Protection of Nature (Copenhagen, 1954):

a) The most specific product should be used, and it should be applied by the method which will produce the least hazard to other wildlife.

b) The quality and quantity of the product used should be in strict accordance with recommendations put forward by official scientific bodies.

c) If wide-scale applications appear to be necessary, possible effects should be fully studied, as regards local conditions, by a qualified biologist, and all desirable measures should be strictly implemented.

Biological control

Insect life is governed by biological and environmental factors, the importance of which cannot be too strongly emphasized. It should be clearly understood that fundamental research in this field has yet to be carried out, and that it must be combined with a study of the reactions of the different types and clones of poplar to their attackers. Research should be directed at the same time to the nature of the parasitism by predatory species and to the degree of resistance or susceptibility of clones.

The use of parasites is undoubtedly the most logical method of control but it can only be carried out by experts. The conditions in which the swarming of large defoliators such as the *liparides* can be abruptly arrested has proved the value of biological control, and has also shown that chemical methods should be used with caution. The best results are obtained at the start of the swarming curve and not when it evens out.

Poplar growers should be constantly on the lookout for clones which are resistant to certain damaging insects, and in this respect it is encouraging to learn that clones resistant to the woolly poplar aphis (*Phloeomyzus*) have been found in Italy.

Mechanical control

Mechanical control is only of secondary importance here. While it may be applied in the preparation of nurseries or plantations, it is only effective for certain larvae which are sensitive to movement, such as grubs. In fact, the mechanical control of xylophagous insects is only carried out in nurseries and young plantations and, to a certain extent, at the time of pruning.

The methods of application vary for nursery plants, for trees growing in lines, in groups or in forest stands. It should be remembered that nursery cultivation is intensive and highly productive, where direct measures, particularly chemical control are feasible, although irksome. On the other hand, in field plantings where the size, longevity and distribution of the trees present technical and economic problems for which there is no easy solution, preference is naturally given to indirect means, such as the appropriate cultural or biological control measures, which are cheaper and whose effect, while less immediate, is often more lasting.

It should be emphasized that vigilance and the satisfactory maintenance of plantings, which permit the immediate and timely elimination of trees most heavily attacked by xylophagous insects, and hence also the destruction of centers of infection, are essential to successful poplar growing.

DIFFERENT KINDS OF ATTACK AND THEIR CONTROL

ATTACK OF THE ROOTS

Melolonthinae

The white grubs or larvae of cockchafers are injurious to all kinds of crops, as they feed on the roots of young plants. They do not usually tolerate the moist soils in which poplars are generally planted, and the damage they cause — which may be considerable — occurs chiefly in nurseries. Cuttings, the bark and cambium of which have been gnawed down to the wood by these grubs, develop imperfectly, can be easily uprooted and finally die off.

The most widely distributed species to be found in Europe is the common cockchafer (*Melolontha melolontha* L.) whose life cycle is normally three years, but may be four years in regions where the winters are long and severe. Cockchafers make large sorties at dusk in the spring and are to be seen flying, sometimes in large numbers, toward isolated trees or tree lines, or on the margins of woods. They occur in fixed years according to the region and can therefore be anticipated. A particular area is said to come under regime I, II, III or IV. The first batch of 20 to 30 eggs is laid in the soil 10 to 20 days after the emergence of the adults in the spring, and this may be followed by a second and sometimes third batch. The most serious damage is caused by the second-year larvae. At the end of June in the third year (fourth year in the case of the fourth cycle), the larvae bury themselves deep in the ground to pupate; the perfect insect is fully grown before the autumn but only emerges the following spring.

Control measures

The insects can easily be exterminated on the trees by spraying, fogging or dusting with hexachlorocyclohexane (BHC) or its derivatives. To achieve maximum efficiency, the treatment must be carried out over an extensive area, which entails collective organization. The grubs may also be destroyed in the ground with the same products, or with chlordane, aldrin or dieldrin, which is mixed with the soil at the time of cultivation at planting.

The forest cockchafer (*M. hippocastani* L.) has a similar evolution in central Europe, whereas its life cycle in eastern Europe may be as long as five years. In North America, the *Melolontha* are replaced by the *Phyllophaga*, of which innumerable species exist, some of them very closely related biologically, with a three-year life cycle and three different regimes, according to the regions in which they are found.

Working the soil during the season when the grubs are active is sufficient to destroy large numbers of them, as they are sensitive to shock and movement.

Capnodis

The Capnodes are large dark-colored *Buprestidae* with a broad prothorax. Their larvae bore sinuous flat tunnels under the bark at the foot of trees or in large roots. They are notorious in the Mediterranean basin for their damage to fruit trees.

C. miliaris Klug.

This capnode, which preys upon poplars and willows, attacks the roots in particular. It has proved especially virulent in Israel, where in certain regions it has caused the death of more than two thirds of the trees, some of them over 15 meters in height.

The attack appears to be closely associated with lack of water: for example, it is rife in sectors which are poorly irrigated and is entirely absent where there is a good water supply. All types are not equally vulnerable; *P. nigra*, *P. alba* and *P. euphratica* are particularly prone to attack, whereas on similar soil *P. deltoides* ssp. *angulata* appears to be little affected. Research is therefore needed to select resistant types, a problem which can only be solved by experiment.

The damage caused by capnodes is aggravated by a secondary attack of another buprestide, *Melanophila picta decastigma* (Bytinski-Salz) which results in the death of the poplar.

ATTACK OF THE WOOD

The principal xylophagous (wood-eating) insects of poplar are divided into two groups: the larvae of the order of Coleoptera (*Cerambycidae*, *Buprestidae* and *Curculionidae*) which are legless and white, and wood-boring caterpillars with legs more or less developed. The *Cerambycidae* larvae (poplar longhorn beetles) are elongated and furnished with dorsal and ventral protuberances, which make it possible for them to advance or retreat in the tunnels. The *Buprestidae* larvae (capnodes) are very broad in the anterior segments of their bodies, while those of the *Curculionidae* are curved.

The group of wood-boring caterpillars includes: the *Sesiidae* common to poplars, which are white and have only rudimentary legs; goat moths,

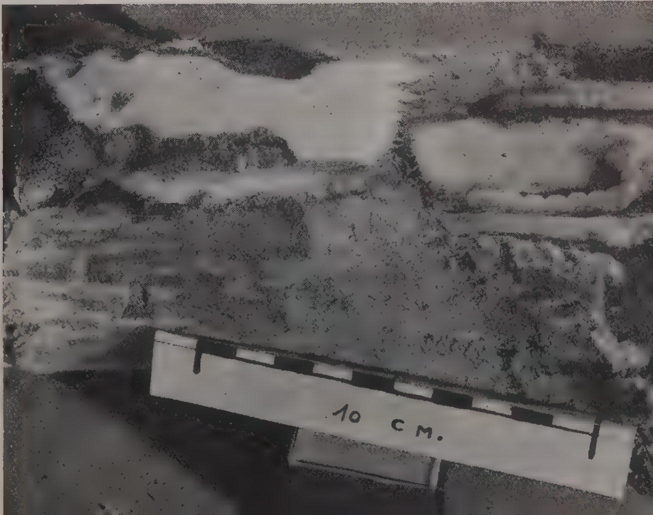


FIGURE 122. – Damage caused by larvae of *Capnodis miliaris*.

Courtesy Neumark

or their large purplish red grubs, and leopard moths whose white larvae — like those of the goat moth — has 16 well-developed legs. These two insects are not peculiar to poplars and are to be found on other species, particularly chestnut, elm, willow and fruit trees.

Damage by xylophagous insects can be detected externally by the ejection of a discolored mixture of frass and sap, a rather marked distortion of the bark or by characteristic swellings (*Saperda populnea* L., *Sesiidae*). Woodpeckers render very valuable service to foresters by feeding on larvae, which they search out in the tunnels by chipping away the wood.

Saperda (Compsidia) populnea L. - Small poplar longhorn beetle

This Cerambycid chiefly attacks the two-year-old stems and branches of cultivated aspens and poplars. A horseshoe scar on the bark and a swelling are evidence of attack. Damage can be very serious in nurseries and young plantings if the leading shoot is attacked; it becomes brittle and is easily snapped off by the wind. The swellings may be so close to one another that the larval tunnels touch; in spite of occlusion, the tree always remains knotty and never grows into a fine specimen.

The growth and breeding habits of this insect are still obscure. The perfect insect, which emerges in May or June, is a longhorn measuring 9 to 15 millimeters; its body is black, covered with fairly dense yellowish hairs; the elytra or wing cases are marked fairly distinctively and the antennae are long and ringed. The female makes horseshoe slits with its mandibles in the bark, the curve facing downward, and lays a single egg in a small cavity at the base of each. The larva which hatches out after about ten days burrows beneath the bark and excavates a horizontal semi-circular tunnel round the branch, ejecting frass and excreta through the hole where the egg was laid. The familiar characteristic swelling is due to the reaction of the tree.

By the end of the summer the larva has grown to 6 to 8 millimeters. In September or October, or sometimes not until the following spring, it reaches the pith and proceeds to excavate a vertical tunnel which may be 4 to 5 centimeters long by the end of the second year; it is in this tunnel that pupation takes place, the adult emerging in May or June of the third year by a round hole pierced in the side of the gall-like swelling.

Control measures

A close watch should be kept on all nurseries and young plantations, and all branches with suspicious swellings removed and burned. The forester should not hesitate to remove infested leading shoots and even to uproot and destroy heavily infested trees which, in any case, will never grow into fine specimens. Adjacent aspen coppice, which is generally highly vulnerable, should also be carefully watched; in fact, it is always advisable to establish nurseries at a distance from aspen plantations.

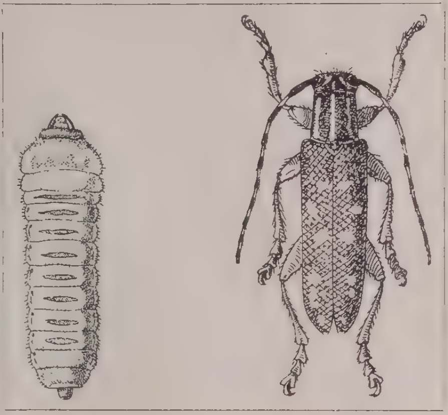


FIGURE 123. – Small poplar longhorn beetle (*Compsidia populnea*). Larva and perfect insect (x 3)

Courtesy *Ecole nationale des eaux et forêts de Nancy*

Up to the present, control of the adults with various products during the laying season has yielded only mediocre results. It should be noted that all clones are not equally vulnerable and, furthermore, that poplars cultivated under good conditions are generally less attacked on account

FIGURE 124. – Small poplar longhorn beetle, gall and emergence hole (actual size).
Courtesy *R. Régnier*

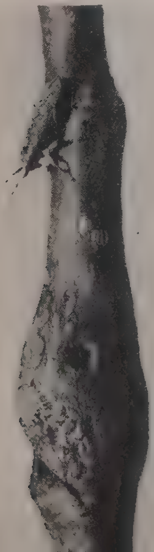
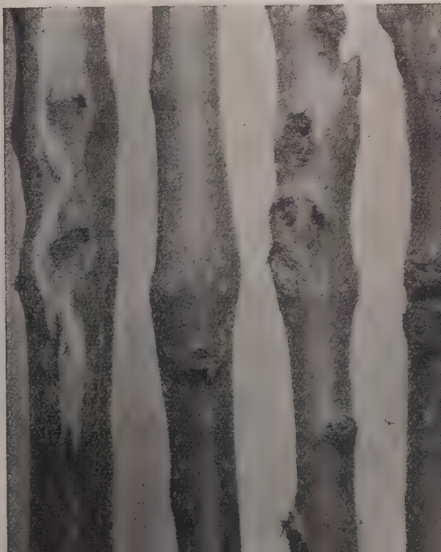


FIGURE 125. – Damage by small longhorn beetle (half actual size).
Courtesy *R. Régnier*



of the gall-forming reaction of the plant, which is more rapid than the development of the egg and the young larva. As a result, many potential attacks do not materialize and the extermal horseshoe mark and swelling do not inevitably mean extensive internal damage.

Saperda (Anaerea) carcharias L. - Large poplar longhorn beetle

This is one of the most destructive of poplar pests, as the larva bores deeply into the inner layers of wood, thereby introducing air and moisture into the trunks of old trees, so that the value of the wood is reduced. Damage is generally localized to the lower part of the tree, descending as far as the roots; it can be detected externally by the rather coarse wood fiber deposited at the foot of the tree, ejected from a round hole in the bark. When the sap rises in the tree, the attack is accompanied by a discharge which is clearly visible in young specimens but on the whole less apparent than with attacks by wood-eating caterpillars. Trees in lines are normally more predisposed to attack than trees in stands or, more especially, in the forest. Medium-aged trees (5 to 10 years) which border highways and grow on only moderately fertile soil, are particularly vulnerable; and danger may be caused to traffic by windblown trees, the bases of which have been severely mined. There does not seem to be any difference in varietal susceptibility but it should be noted that black poplars (*Aigeiros*) are particularly liable to attack by the large poplar longhorn beetle. This beetle is very widely distributed and is found over a large part of Europe, in Siberia and even Korea. In North

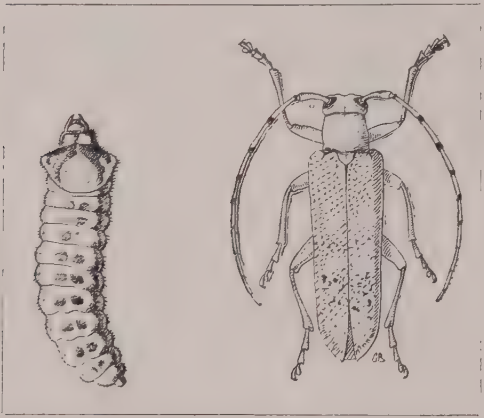


FIGURE 126. – Large poplar longhorn beetle (*Saperda carcharias*). Larva (x 2) and perfect insect (x 2).

Courtesy *Ecole nationale des eaux et forêts de Nancy*

FIGURE 127. – Timber infested by *Saperda carcharias.*

Courtesy *R. Régnier*

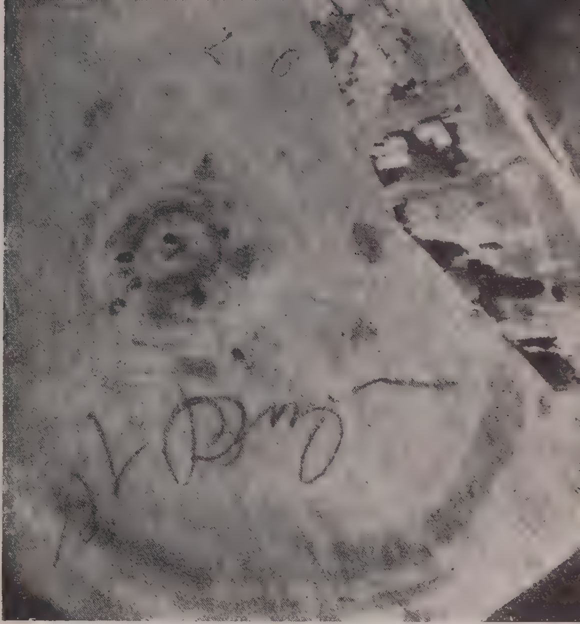


FIGURE 128. – Control measures against *Saperda carcharias.*

Courtesy *R. Régnier*

America it is replaced by *Saperda calcarata* Say (poplar borer), which attacks the heartwood.

This is a large longhorn beetle (20 to 30 millimeters), covered with a reddish or grayish down; it has ringed antennae, longer than the body in the case of the male, with broad deeply punctured wing cases. The perfect insect appears in July or August and is active until October; it attacks the tender bark of young stems. The eggs are laid at the base of the trunk. In the case of old trees, the female lays the eggs singly in fissures in the bark; in young trees the female chooses a point where the bark is smooth, makes a deep incision with its mandibles and deposits the egg inside the wound. The egg does not hatch out until the following summer: the young larva bores a tunnel beneath the bark, then burrows horizontally into the outer layers of the wood toward the heart of the tree, which it reaches before the winter. It descends to the roots, then burrows upward again through the center of the tree. While excavating this last ascending tunnel the larva prepares the exit hole through which the adult will finally emerge; here it pupates in June of the following year, and the adult emerges 15 days later. This life cycle lasts for a minimum of two years.

Control measures

Mature trees should be felled. In regions which are subject to attack by this deadly woodborer, a close watch should be kept on trees bordering roads and on the edge of forests.

Up to the present no entirely satisfactory and economic remedy has been found. Immediately the first signs of infestation are visible, precautions should be taken to protect the other trees. The most usual treatment is to paint the trunk up to a height of 1.50 meters with carbonyl or with a mixture of clay, chalk and cow dung before the adults emerge. To reach the larvae in the tunnel, the hole through which frass is ejected is first cleared and an insecticide stick (Antitarlo), which gives out a toxic gas, inserted. Alternatively, the hole may be plugged with cotton wool impregnated with carbon disulphide (highly inflammable) or crystals of paradichlorobenzene.

Saperda perforata Pall.

This species, which only attacks the mountain strains of aspen, appears to be of fairly local occurrence, although it sometimes causes serious damage, for example, in the Valley of the Vallouise in the High Alps (A. Kh. Jablokoff). The larva develops in the outer wood layers underneath the bark, and only penetrates deeper in order to pupate (A. Simon). An attack appears to occur when the tree has been weakened by attacks from other xylophagous insects (*Cossus*, *Sesiidae*).

It is not uncommon to find other *Cerambycidae* on decaying aspen; for example, *Xylotrechus rusticus* L., *Necydalis major* L., *Acanthoderes clavipes* Sch., whose tunnelling aggravates the damage caused by *S. perforata*.

Capnodis

In addition to *C. miliaris* Klug., which was referred to earlier and whose attacks appear due to an inadequate water supply, other species of *Capnodis* have been reported as injurious to poplars in the Near East, in particular, *C. cariosa* Pallas, whose larvae bore wide, sinuous, deep tunnels, with a flat base in the cambium beneath the bark at the foot of the tree. These tunnels are carpeted with fine frass. *C. cariosa* also attacks vigorous trees.

C. tenebrionis L.

This, the chief enemy of peach and apricot trees in the Mediterranean basin, also causes serious damage in Syria to *P. nigra* cv. ' Hamoui '.

Reference to the biology of this insect, which has been the most thoroughly studied of all, shows that the larvae develop exclusively in living tissue. The adults hibernate in a variety of sheltered places and emerge in the spring. Sorties occur over a period and the insects are very active in hot weather, when they strip the bark off young shoots, without however causing serious damage except in young plantings. The breeding season is from June to September and the eggs are laid in the soil close to the trunk. The eggs hatch out after about ten days and the larvae take from one to two years to reach maturity. They are white, legless grubs and attain a large size (60 to 65 millimeters), the prothorax is enlarged and strongly chitinized, the abdominal segments rectangular, flat and clearly separated.

Control measures

Capnodes are always difficult to control, owing to the way in which sorties are spread over a period and to the insidious work of the larvae. Research by Feron on *C. tenebrionis* has proved the efficiency of two products: hexachlorocyclohexane (BHC) in its various forms[1] and chlordane incorporated with the soil before the egg-laying season. Spraying with a suspension of 2 grams per liter of BHC technique or 3 liters of chlordane per tree, and dusting with 50 grams per tree of a mixture of inert powder and an active substance is recommended; the operation should be repeated, taking particular care to treat the area around the collar. Working the soil around the foot of the tree appears to reduce infestation.

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[1] Lindane or " gamma isomer " of BHC sprayed on the trunk and on the ground at the foot of the tree at the rate of 10 grams to 100 liters of water, swiftly exterminate the adult.

Several Buprestids attack poplars belonging to the various groups, particularly black poplars and aspens. They burrow beneath the bark into the cambium layers and then into the heartwood, hollowing out sinuous, spiral, rather shallow tunnels. The larvae are small, white and flattened in shape, the front of their bodies thicker and chitinized. Attacked trees can be detected by the premature discoloration of the leaves and the gradual withering of the shoots. The Agrilus usually attack old, sickly or frost-damaged trees; this is the case, for example, with *A. ater* L. (*sexguttatus* Brahm).

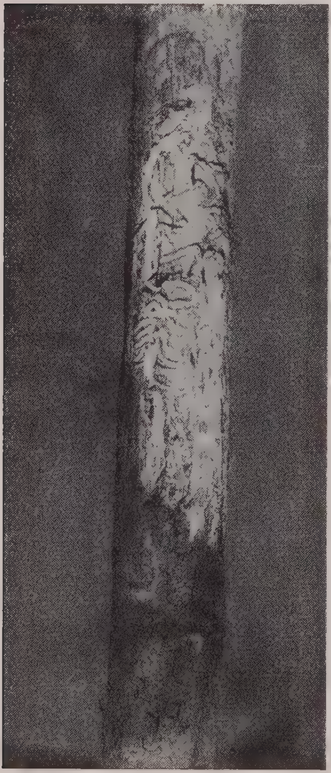


FIGURE 129. – An aspen *Agrilus*.

Courtesy *R. Régnier*

In addition to these Buprestids, mention should also be made of ***Chrysobothris affinis*. Fab.,** a polyphagous species which attacks fruit trees and broad-leaved species such as oak but which is reported in Spain to be a serious pest on poplars; and ***Poecilonota variolosa* Paykull,** which causes damage to aspens, white poplars and black poplars of the *nigra* group. This Buprestid, which is not uncommon on decaying trees, is reported to be injurious to young trees whose bark is not, however, sufficiently thick to ensure the complete evolution of the larvae. The eggs are generally deposited at the foot of the poplar, the larva descends first toward the roots, then bores upward in the trunk, burrowing a tunnel beneath the bark in which to pupate. This species, which is sometimes found in large branches, has a very wide distribution. It is found over a large part of Europe from Scandinavia to the Mediterranean basin, in North Africa, western Asia and Transbaikalia. Infested trees should be felled in winter, debarked and the bark burned.

Cryptorrhynchus lapathi L.

This insect, which attacks willow, birch and alder, is mainly a pest in nurseries and young plantings, where between 60 and 80 percent of the plants may be affected. It attacks the stems and shoots which wither and break off. Externally, the damage can be detected by the bark turning brown, by superficial malformations resembling cankers, and by the ejection of a mixture of frass and sap.

This very characteristic weevil, which is 6 to 9 millimeters in length, has a squat body; the rostrum is curved, and the wing cases brownish-black, the basal third covered with white scales. The perfect insect emerges in August. It gnaws the bark of young shoots, hibernates in the mossy crevices of the bark, in larval tunnels or other sheltered places, and does not emerge until the mating season in the spring. The female lays the eggs, often several together, either in a small hole hollowed out with its rostrum close to the buds, or in wounds caused by pruning, or in fissures and abrasions in the bark. The larva only hatches out the following spring, burrows into the cambium and then bores a tunnel deep into the wood. Pupation takes place in the vicinity of the hole through which the frass is ejected, in a hollow padded with wood fiber; this stage lasts from 15 days to three weeks, and the insect emerges through the aperture prepared by the larva. The life cycles may overlap, and it is not unusual to find at the same time both insects and larvae in the same plantation.

Control measures

Willows, birch and alder should be removed from the vicinity of breeding grounds of this insect, since these species are natural centers of contamination. A close watch should be exercised in nurseries and young plantings, and trees which have been attacked should be uprooted and burned, so as to arrest the injury at its first appearance.

Local research alone can determine the best time to carry out the recommended treatment of fumigating or dusting nurseries and large plantations with insecticides. Treatment would appear feasible at the time when the insects emerge and attack the young shoots in August.

Sesiidae

Hornet moths prey chiefly on black poplars. It is important to distinguish between the large hornet moth (*Trochilium apiforme* L.) which attacks in preference fairly large trees, and the small hornet moths (*Sciap-*

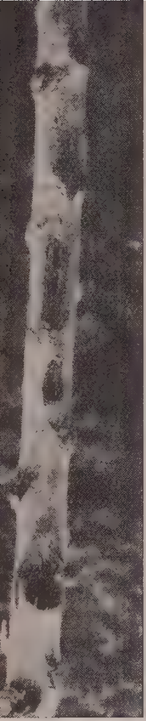


FIGURE 130. – Left: *Cryptorrhynchus.* Woodpecker damage.
Courtesy *R. Régnier*

FIGURE 131. – Right: Damage caused by *Cryptorrhynchus lapathi.*
Courtesy *R. Régnier*

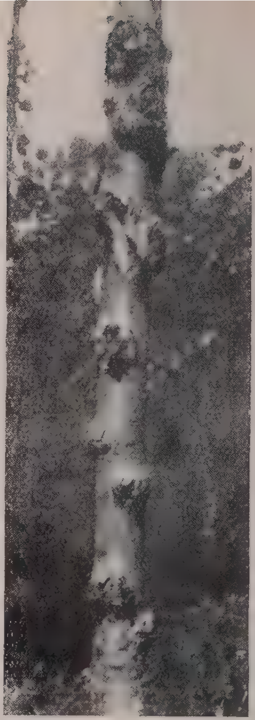
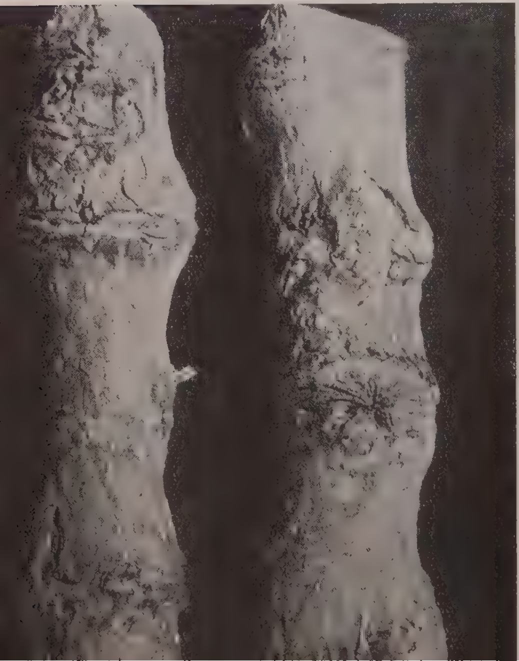


FIGURE 132. – *Cryptorrhynchus lapathi* ("coffee bean"). Healing scars left after infestation.
Courtesy *Istituto Casale Monferrato*

FIGURE 133. – Damage by woodpeckers predatory of the larvae of longhorn beetles and hornet moths. Courtesy *R.Régnier*



teron tabaniforme Rott. and *Sc. melanocephala* Dalm.) whose attacks are for the most part on young plantings and low branches. The caterpillars burrow deep, sinuous tunnels and the external signs of damage are irregular-shaped swellings, the result of the violent reaction of the tree, which differ from those caused by the small poplar longhorn beetle. Moreover, stems which are attacked do not bear horseshoe scars.

Damage can be extensive, and that caused by the large hornet moth may be mistaken for damage caused by the large poplar longhorn beetle. Roadside plantings are generally more prone to attack than groups of trees or forest plantations. Trees planted in poor or dry soil are also more susceptible. Old poplars left standing too long encourage swarming of the insect.

The moths are characterized by long, narrow, partly transparent wings and by their body coloring which gives them the appearance of hornets or wasps. The antennae are black and the body scaly.

Trochilium apiforme L.

The large hornet moth (*Trochilium apiforme* L.) takes two years to evolve. The female deposits the eggs singly, which are red, at the base of the trunk where the main roots lead off. The caterpillars hatch out

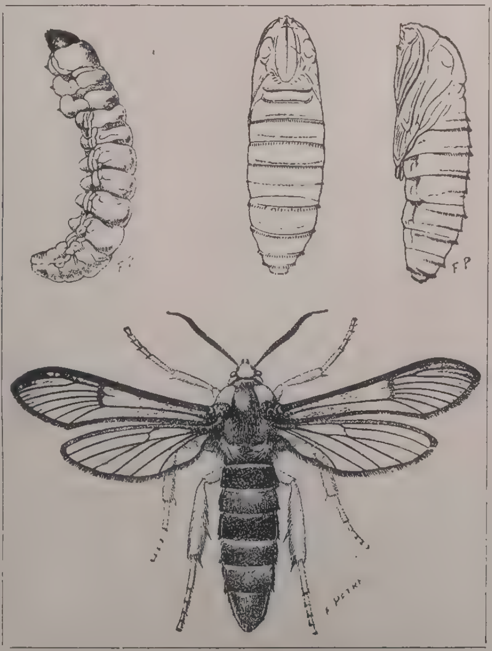


FIGURE 134. – Large hornet moth (*Trochilium apiforme*). Larva, chrysalis and perfect insect (x 2).

Courtesy *Ecole nationale des eaux et forêts de Nancy* after a month, burrow under the bark, gnaw into it and hibernate there. In the second year they excavate long tunnels in the wood of the roots and trunk. Pupation takes place in April or May of the following year in a cocoon composed of woody fibers.

If a planting is established in the vicinity of old, attacked poplars, a close watch should be kept, and at the first signs of infestation treatment should be given as recommended for the large longhorn beetle.

Sciapteron tabaniforme Rott.

This hornet moth is more local in occurrence and appears attracted to different ecological conditions, notably moister sites; it is chiefly harmful to young plantings. The rounded shape of the scars due to the occlusion of the exit holes has earned it the name of "coffee bean" among foresters. Varieties with somewhat knotty trunks are the most susceptible but it is not unusual to find attacks on smooth-barked poplars. The wounds of clones with a rapid growth rate are soon healed.

The moth, which is smaller than that of the large hornet moth, has brown, opaque forewings, and a shiny blue-black abdomen girdled with

FIGURE 135. – Damage by small hornet moth (*Sciapteron tabaniforme*) to a 5-year-old poplar.

Courtesy *Zoological Research Station, Rouen*

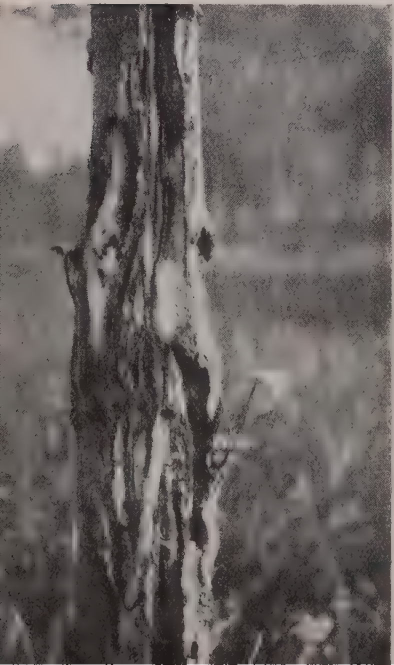
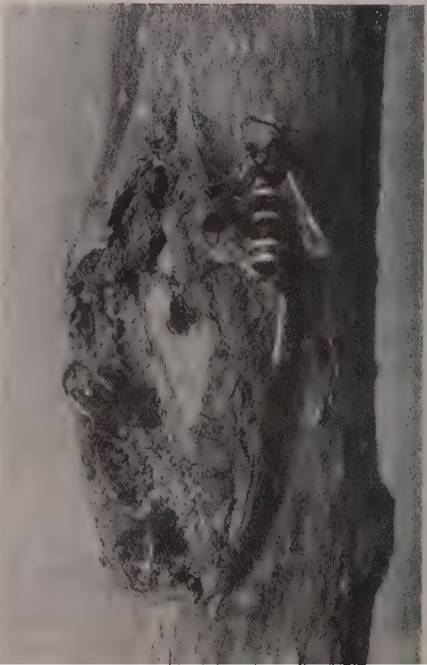


FIGURE 136. – *Sciapteron tabaniforme* (actual size).

Courtesy *R. Régnier*



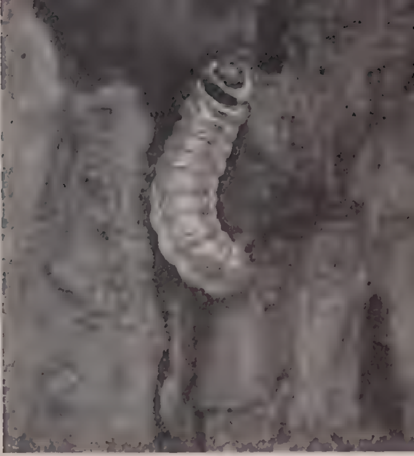
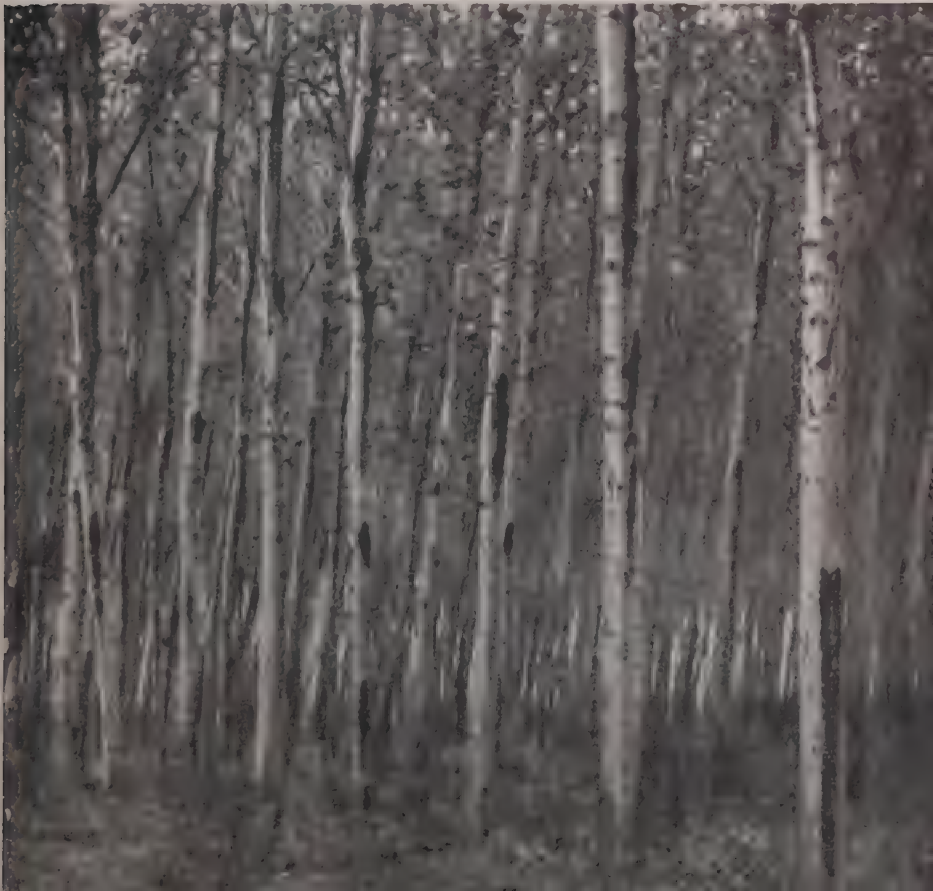


FIGURE 137. – *Cossus cossus* L.

Courtesy *R. Regnier*

FIGURE 138. · Trees infested by xylophagous caterpillars (*Cossus cossus* L.), showing discharge from trunks. Province of Pavia, Italy.

Courtesy *Istituto Casale Monferrato*



yellow. The female lays its eggs in June or July in the pruning wounds or furrows in the bark; the white larva which hatches out shortly afterward excavates a small hollow beneath the bark. In July or August, when the sap rises, the cambial layer reacts by swelling. Only in the following spring does the caterpillar penetrate deeply into the wood, excavating an ascending longitudinal tunnel; it is fully grown by the autumn of the same year and pupates in the tunnel, the moth emerging the following year. This hornet moth also preys on willows.

Trochilium melanocephala Dalm.

Attacks aspens.

Cossus and *Zeuzera*

These wood-boring caterpillars are not peculiar to poplars but the former in particular frequently attacks them and can cause much damage.

The most harmful species, *Cossus cossus* L., is a large, purplish-red caterpillar whose life cycle is from two to three years. The moth, also large, hatches out in July and during the daytime rests motionless against the bark. The female lays its eggs in crevices in the bark, abrasions, pruning wounds and cankers. As soon as they are hatched the young caterpillars burrow into the interior of the tree, excavating sinuous tunnels which may be as large as 10 to 15 millimeters in diameter. The caterpillar itself is from 70 to 100 millimeters in length and pupates in May at the entry to a tunnel or at the foot of the tree, in a cocoon composed of a mixture of wood fiber or earth. The moth emerges several weeks later. It emits an unpleasant pungent odor, which is also noticeable in its excreta. Attacks by the goat moth can easily be detected, even from a distance, by the discharge from the trunks; such attacks can be extremely dangerous since, besides internal damage, the goat moth acts as a vector in spreading weeping canker to a height which other species do not reach.

An attack can easily be located by the excreta at the foot of the tree; those of *Cossus* are long, irregular in shape, pungent and very discolored, whereas those of *Zeuzera* are cylindrical and regular in shape.

The caterpillar of *Zeuzera pyrina* L. is white spotted with black and smaller than that of the goat moth. It is generally attracted to medium-sized trees and, once it has reached the center of the tree or branch, continues excavating along the axis. The moth has white wings dotted with black.

Control measures

Pruning wounds should be coated with tar, carbonyl or anthracene oil at a strength of 10 percent, and the apertures cleared and painted with birdlime to prevent the exit of caterpillars and moths at their customary season (spring). To arrest attacks, old trees (poplars, willows, chestnuts and apple trees) should be removed from the vicinity, and similarly all cankered trees which are centers of infection. Insecticide sticks (Antitarlo) are effective but the direct control measures as recommended for the large poplar longhorn beetle are often difficult to apply, since the forester is frequently confronted with multiple attacks which are difficult of access. In this case, felling is the only solution. Control measures which are both practicable and economic have yet to be developed.

Cossus terebra Schiffer

This species, which is found in the Danubian countries, the Near East and as far north as Siberia, is also a serious pest on poplars. Another injurious insect of the *Cossidae* family, *Paropta henleii* Rotsch, is also reported in the Near East.

Cambium borers

Small dipterous larvae of the *Agromyzidae* family (*Dendromyza*) periodically bore tunnels into the cambium. The outer layer of wood is thus marked each year, with the result that when the logs are peeled for veneers, the larval tunnels are visible. Although the damaged cell tissues heal over, lines of weakness occur which make the wood brittle and hence unsuitable for thin veneers of 8 to 10 millimeters.

In regions where attacks are frequent, serious losses can be avoided by debarking several sample billets before proceeding to saw them. If shallow tunnelling is found, it is advisable to reserve them for thick veneers (20/40/10 mm.). Direct control measures are practically impossible, as the damage only becomes evident after felling.

Cimbex

Sometimes large circular swellings are to be seen on young stems; these are the result of the bark being attacked by a *Tenthredinidae* of the genus *Cimbex*. The tree reacts violently and subsequent occlusion is marked by the development of scar swellings. An attack is normally only serious when there is a center of infection in the neighborhood.

ATTACK OF THE BUDS, YOUNG SHOOTS AND FOLIAGE

A large number of insects (Coleoptera, Lepidoptera and Hymenoptera) attack the buds, young shoots and foliage of poplars. Their economic importance varies very considerably; the majority are polyphagous but some, on occasion, are serious pests. Only those insects which do serious damage are mentioned here, and for the description and biology of the others, reference should be made to specialized works on the subject.

Coleoptera

The most injurious of these belong to three families of phyllophagous or leaf-eating insects: the *Melolonthidae*, *Curculionidae* and *Chrysomelidae.*

Melolonthidae

Mention has been made earlier of the cockchafers, whose larvae or white grubs attack the roots. At the adult stage cockchafers are very fond of the tender foliage of poplars, particularly if there are no adjacent oaks, beech or hornbeams, which are their preferred food. Owing to their three- or four-year life-cycle, and to their regimes, they are only troublesome in a particular locality in certain years and for about a month. They have a marked preference for late flushing poplars. Methods of eradicating them have already been described.

Curculionidae

Orchestes, *Rhynchites* and leaf-eating weevils are common on poplars. The larvae of *Orchestes* (*O. populi* F. and *O. rufitarsis* Germ.) mine the leaves which roll up and dry out; the damage often passes unnoticed. The *Rhynchites* (*Byctiscus populi* L. and *B.betulae* L.) roll the leaves in the shape of a cigar and the female lays its eggs singly in the folds. When the " cigars " are very numerous on a young tree, the rate of growth falls off appreciably but the attack is generally localized.

This is not the case with the leaf-eating weevils (*Polydrosus* and *Phyllobius*), of which several species (*Polydrosus impressifons* Gryll., *P. mollis* Strom., *P. sericeus* Schall., *Phyllobius oblongus* L., which has brown wing cases, *P. piri* L., *P. viride-aeris* Laich.) sometimes do damage in the nursery where they nibble the edges of young shoots and leaves. These weevils are not peculiar to poplars and are to be found on many fruit and forest trees. They are easily exterminated by spraying or dusting the trees with synthetic organic compounds.

Chrysomelidae

To this family belong the defoliators which do most harm in nurseries. Both the adult insects and larvae feed on the foliage, stripping the leaves and leaving only the midrib and veins; in this way they may even cause the death of young plants. The most common species are the *Melasoma* (*Lina*) and the *Phyllodecta* (*Phratora*) which are strongly attracted to the *Salicaceae*. The distribution of some of these defoliators extends over a large part of the Northern Hemisphere.

The *Melasoma* (7 to 12 millimeters) have short antennae, an oval, markedly convex body, the ground color of which is a greenish-blue with a metallic luster, and red wing cases. *M. tremulae* F. is slightly smaller than *M. populi*, and is distinguished from it by the absence of markings at the tips of the wing cases. It preys chiefly upon aspen. The female lays its eggs, which are orange, in batches of 10 to 25 on the undersurface of the leaves or sometimes on the bark (*M. tremulae*); the female may lay as many as a thousand eggs. The larvae, which emerge after about ten days, have black heads and whitish bodies with black protuberances on the segments; when touched, they discharge small white drops of a pungent substance from nipples on the sides of their bodies to protect them from their enemies. The larvae at first live in colonies, dispersing after three weeks; they pupate by suspending themselves by the extremity of their abdomen. Pupation lasts for about ten days, completing the life cycle of approximately six weeks. There are at least two generations a year. The perfect insect hibernates on the undersurface of dry leaves.

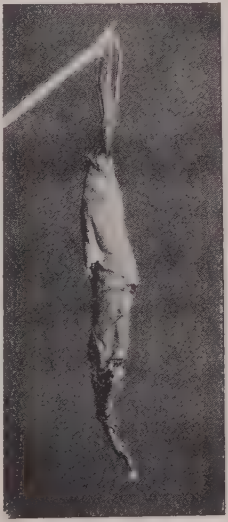


FIGURE 139. – *Byctiscus populi* (?). Leaf rolled into a "cigar" shape.

Courtesy *Istituto Casale Monferrato*

The *Phyllodecta* (*P. vitellinae* L. and *P. vulgatissima* L.) are elongated, small (4 to 5 millimeters) and green or blue in color with a gold sheen. The larvae, which are at first yellowish-white, become gray and later black; they also exude a pungent substance. The insect hibernates in a variety of sheltered places (tree stumps, bark or walls). It emerges in the spring and lays its eggs in batches or 10 to 30, generally arranged in two or three rows, on the undersurface of leaves. The eggs lie flat on the leaf, not perpendicular to it as in the case of *Melasoma*. After from three to ten days, according to the temperature, the small larvae hatch out and proceed to feed on the lower parenchyma. At first they remain in colonies but later disperse; they moult three times, and at the end of 25 to 30 days, pupate, in the soil. The perfect insect emerges 10 to 15 days later and, like the larva, attacks the foliage voraciously. The adults collect on the leaves in the evening and colonies of 15 to 20 may often be seen on the same leaf. Hatching is spread over a period, and hence eggs, larvae and adult insects may all be found at the same time. There are two, and sometimes three, generations. In North America a closely allied species, *Phytodecta americana* Schaeff. (American poplar leaf beetle) causes similar damage to nurseries and young plantings.

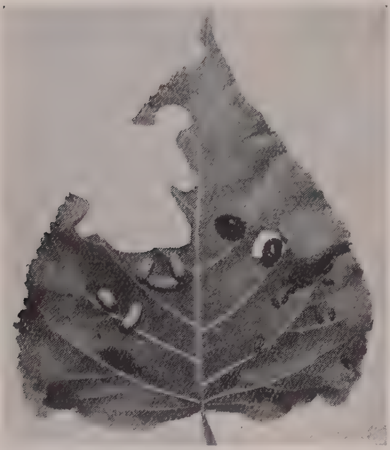


FIGURE 140. – *Melasoma populi*.

Courtesy *Istituto Casale Monferrato*

In addition to these large defoliators, another Chrysomelid (*Plagiodera versicolor* Laich.), a brilliant bluish-green in color, is found sporadically. It is known throughout the Northern Hemisphere and is a serious pest on willows, attacking leaves and buds. There are also small flea beetles (*Chalcoides*), 3 millimeters long and brilliantly colored (*Ch. aurata* and *Ch. aurea* are greenish-gold), whose third pair of legs are larger than the others and enable them to hop. These insects literally riddle the leaves with holes. *Zeugophora scutellaris* Suffr. (European leaf miner), introduced into the Unites States in 1918, mines the terminal leaves of *P. deltoides* in nurseries.

All these small insects can easily be destroyed by spraying or dusting with DDT, BHC separately or in combination, or phosphoric esters. Treatment should be carried out as soon as the first larvae appear (at the beginning of May).

Lepidoptera

The number of caterpillars which feed on poplar foliage is considerable; there are more than a hundred in western Europe alone.

Stilpnotia (=*Leucoma*) *salicis* L. - Willow liparid

This, undoubtedly the most destructive black poplar leaf miner,[2] is distributed over the whole of the Northern Hemisphere, and in a large-scale attack is capable of stripping the foliage from entire plantations.

The moth, which is a beautiful silvery white with a brown abdomen and black legs, may be seen in flight from the end of June to August, depending on the region. The eggs are deposited in batches on the bark and are overlaid with a characteristic satiny white fluid. Fifteen to 20 days later the caterpillars hatch out, giving a second generation at the end of August as, for example, in Italy or northern France. This new generation feeds on the foliage for several days and then moults. They collect into groups of two or three to spin, under the lichens on the bark, small silky hibernation sacks, only emerging the following spring, when they proceed to feed on the young leaves even into the crown of the tree. The adult caterpillar is black on top, spotted with white, and has lateral tubercles covered with reddish hair; the body is purplish-brown underneath. Pupation takes place at the end of May or beginning of June in a loose silky cocoon which the caterpillar spins amongst the remnants of the foliage or in the crevices of the bark. The moth hatches out 10 to 15 days later. The male is active, whereas the female is heavy and rarely flies.

Control measures

This destructive pest is attacked by parasites, Tachnids, Ichneumonids Chalcids, entomophytic fungi and micro-organisms which arrest its reproduction and are increasingly active, the more intense the swarming. It can also be destroyed by dusting, spraying and fogging with synthetic insecticides but such measures should be taken very early in the spring and, if possible, directed against the young caterpillars. The amount of time available at this season is unfortunately very short and therefore the treatment of large trees creates economic difficulties.

The more important defoliators of fruit and forest trees, amongst which should be mentioned ***Lymantria dispar*** L., ***Malacosoma neustria*** L., ***Operophthera*** **(*Cheimatobia*)** ***brumata*** L., are common on poplars and capable of causing considerable damage. The gypsy moth (*L. dispar*), since its introduction into North America, has become one of the great forest enemies. The first attacks, dating back to 1869, were on poplars. Late-flushing clones appear the most susceptible to inch worms.

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[2] This species also attacks white poplar and aspen.

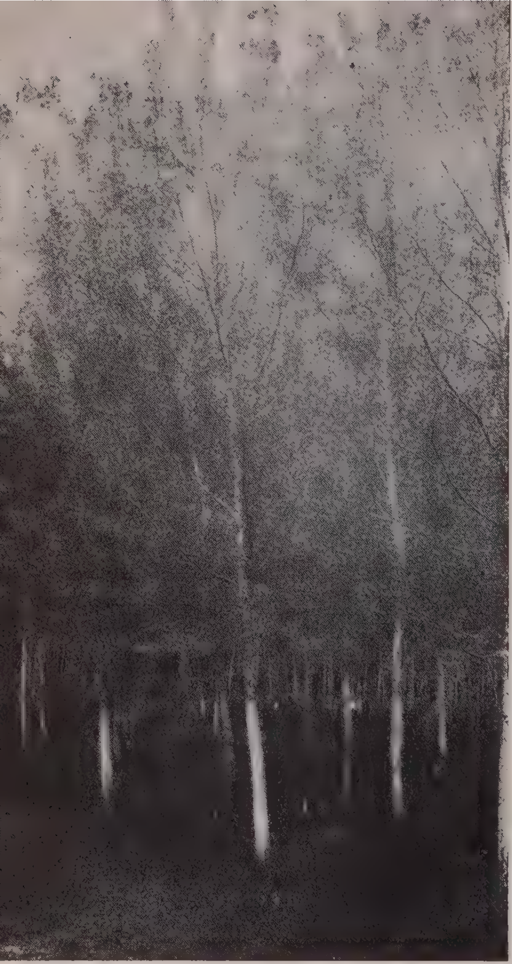
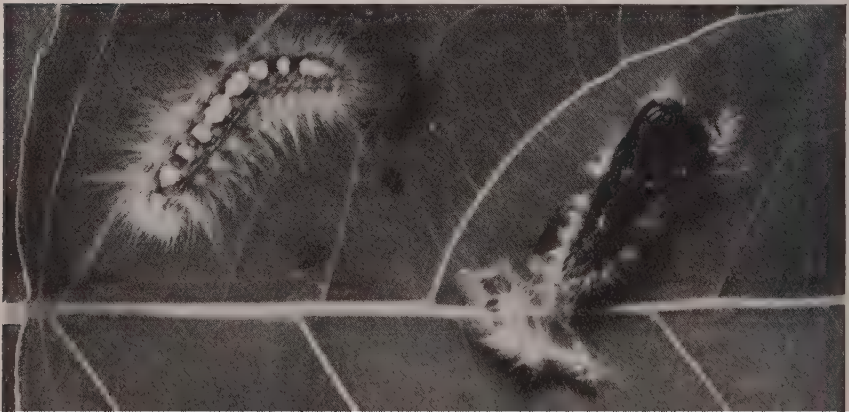


Figure 141. – Damage by *Stilpnotia salicis.*

Courtesy *W. Vivani*

Figure 142. – *Stilpnotia salicis.*

Courtesy *Istituto Casale Monferrato*



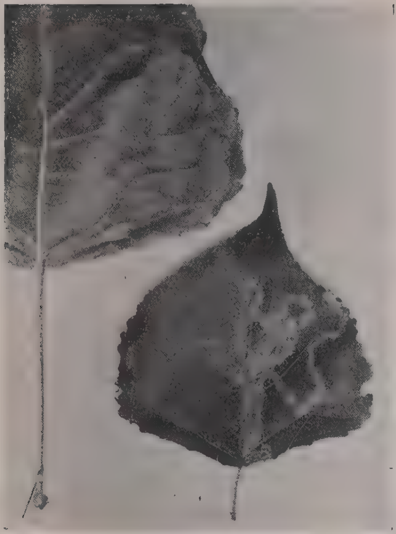


FIGURE 143. – *Phyllocnistis suffusella*, at Dommartin-les-Toul, France.

Courtesy *Joly*

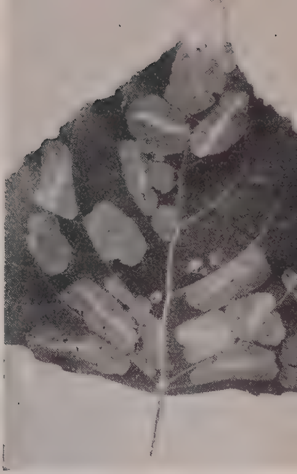
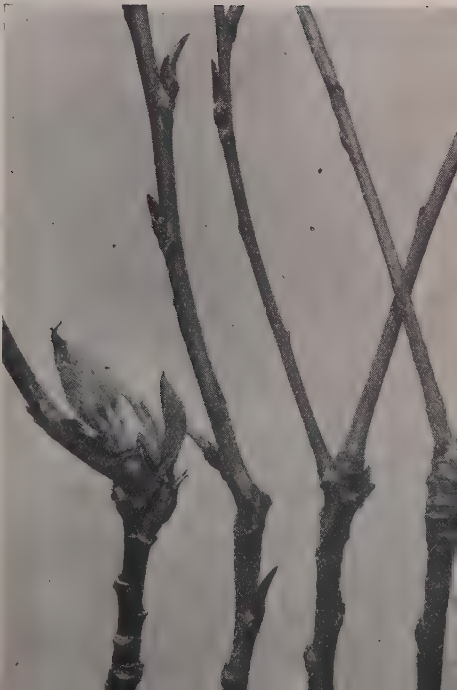


FIGURE 144. – *Lithocolletis populifoliella* (undersurface of leaf) at Troyes, Aube, France.

Courtesy *Joly*

FIGURE 145. – Distortion due to *Semasia* (*Gypsonoma*) *aceriana* on:
(1) *P. candicans*
(2) *P.* ' robusta '
(3) *P.* ' robusta '
(4) *P.* ' serotina ' (half actual size)

Courtesy *R. Régnier*



Malacosoma disstria Hbn. - Forest tent caterpillar

This caterpillar, which periodically lays waste broadleaved forests in the center and northeast of North America, is regarded in Canada as one of the chief pests of *Populus tremuloides.*

The most recent to appear in Europe is the fall webworm (*Hyphantria cunea* Drury), a species closely allied to *S. salicis*, and recently introduced into central Europe from the United States. It produces two or three generations a year. The caterpillar is very active and attacks many broadleaved species, including poplar. The rapidity with which it has invaded Yugoslavia and Austria is significant, and its further spread needs to be checked carefully. The chrysalis can attach itself to crates, wood or wagons, etc., and thus moved over considerable distances.

Large single caterpillars, for example, *Smerinthus populi* L., *Dicranura vinula* L., *D. bifida* Hb., *Catocala electa* Bork., are generally an easy prey for birds and parasites and are rarely very destructive. Moreover, their very obvious damage makes them easy to catch and destroy in nurseries.

Leaf rollers and leaf miners

Under this heading are grouped a large number of small insect pests which attack buds and young shoots, which the caterpillars encase with silk threads often with their excreta, or which mine the leaves. Leaf miners may be extremely numerous; some attack black poplars, others white poplars and aspens. The most common leaf miners belong to the genera *Lithocolletis*, *Phyllocnistis* (*suffusella* Zell.), *Cemiostoma*, *Nepticula*, and sometimes cause inordinate damage. The noctuid *Earias vernana* Hb., which rolls up leaves, catkins and buds, and the small leaf rollers *Archips conflictana* Wlk. (found on *Populus tremuloides* in Canada), *Tortrix diversana* Hb. and *Epiblema nisella* Clerck, are also often mentioned, although they are of lesser importance.

Among the leaf rollers, *Semasia*, of which there are several harmful species, is in a special category and attacks buds: *S. neglectana* Dup., *S. oppressana* Dup., can do considerable damage by causing the failure of terminal buds to develop, and particularly *S.* (*Gypsonoma*) *aceriana* Dup., the most widely distributed species, whose caterpillar causes young shoots to die back, with the formation of a characteristic swelling and the abnormal development of secondary shoots. Such attacks can make many nursery plants unusable if the stem is not cut back sufficiently early below the swelling to enable a new leading shoot to develop. Attacks are frequent on all poplars.

The use of insecticides against curculionids and chrysomelids in nurseries provide a means of limiting damage. The early removal of distorted shoots allows new growth to replace them.

Hymenoptera

Several species of false caterpillars (*Tenthredinidae*) are found on *Salicaceae*, some of them extremely injurious on account of their rapid breeding. The most widely distributed is *Trichiocampus viminalis* Fallen (poplar sawfly), which occurs both in Europe and North America and which attacks black poplar and aspen. *Pteronidea ventralis* Say sometimes does great harm in Canada, where the elm sawfly, *Cimbex americana* Leach, occasionally preys on poplars.

The larvae have ten pairs of legs, are yellow with black heads, and have black spots on the abdominal segments. Their mode of attack is characteristic: they live in colonies on the undersurface of leaves, on which they feed methodically and progressively, frequently with the front portion of the body held erect in a characteristic position. Pupation takes place in the soil in a silky cocoon and the perfect insect flies off in June.

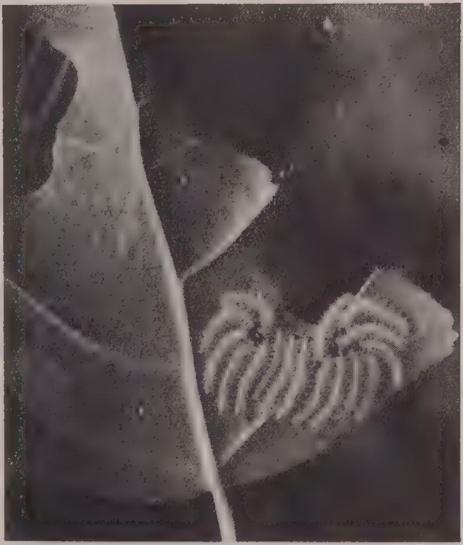


FIGURE 146. – Infestation by false caterpillars (*Tenthredinidae*).

Courtesy *Zoological Research Station, Rouen*

Swarming is generally arrested by parasites. Large-scale attacks can be avoided by dusting or spraying early with BHC or DDT, false caterpillars being more vulnerable to this treatment than true caterpillars.

Gall wasps or gall midges

To this group belong the insects and mites which, by attacking the tree, cause it to react with distortions and the characteristic cellular formations which are peculiar to each species and are known as galls. It

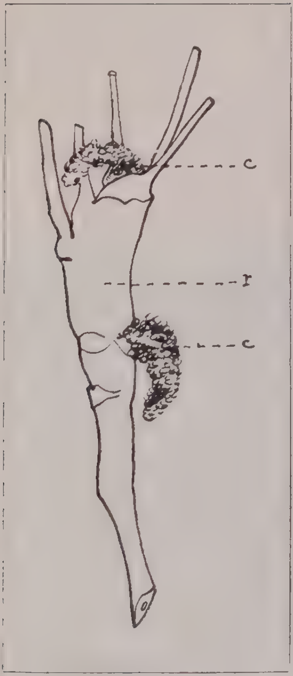


FIGURE 147. – Damage by *Semasia aceriana* (actual size) showing swelling (*r*) and shell of nymphalid (*c*).

Courtesy *R. Régnier*

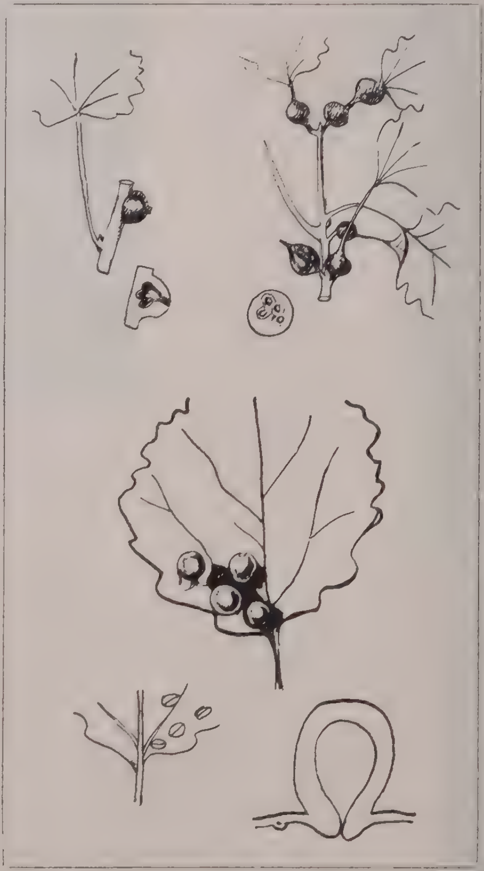


FIGURE 148. – Dipterous Cecidomyids on *P. tremula: Harmandia petioli* Kieff. and *Harmandia tremulae* Winn.

Courtesy *C. Houard*

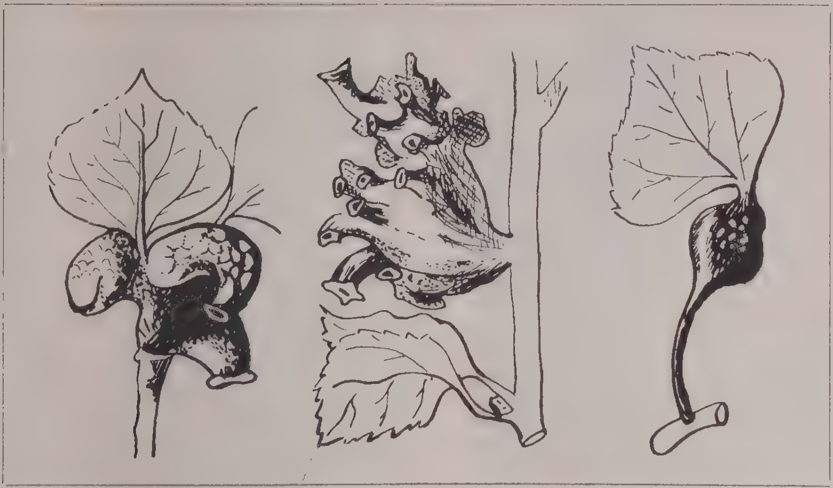


FIGURE 149. – Gall-forming aphids on *P. nigra: Pemphigus bursarius* L.; *P. vesicarius* Pass.; *P. piriformis* Licht.

Courtesy *Lichtenstein*

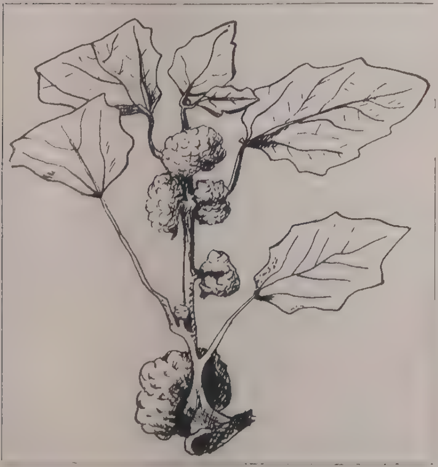


FIGURE 150. – Gall-forming midges on *P. alba: Eriophyes populi* L.

Courtesy *C. Houard*

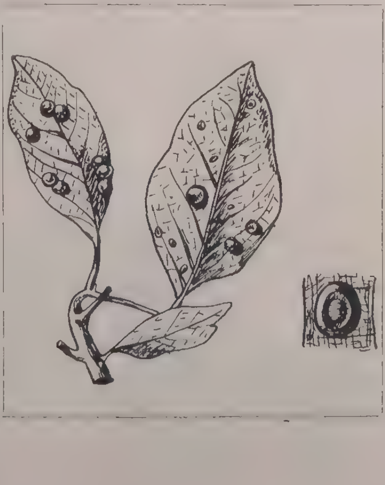


FIGURE 151. – *Psyllidae* gall-formers on *P. euphratica*.

Courtesy *Rübsaamen*

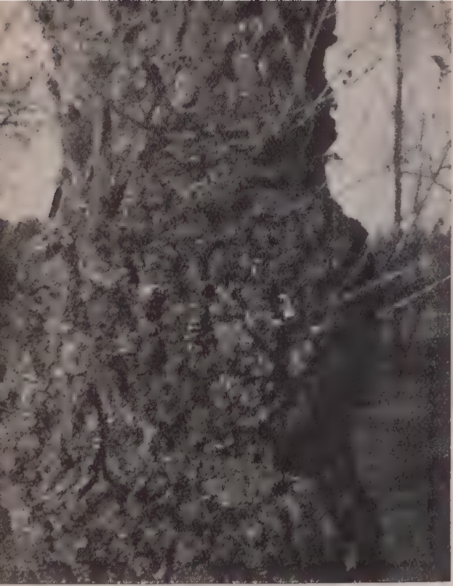


FIGURE 152. – Attack of *Eriophyes populi* on *P. nigra*.

Courtesy *R. Régnier*

is noteworthy that galls are more common in natural stands than on cultivated poplars. Two of the most important gall-forming poplar pests have been examined earlier under different headings: *Saperda* (*Compsidia*) *populnea* and *Semasia aceriana*, which cause characteristic swellings of uniform shape.

Other gall-forming insects are sometimes very numerous: for example, the Cecidomyids (*Harmandia, Lasioptera*) and the aphids (*Pemphigus*) which attack buds, young stems and different parts of the leaf (petiole, veins, midrib and margin); the mites too, for example, *Eriophyes populi* L., whose attack on buds causes the formation of large cauliflower-shaped pink and green galls, which are to be seen on the trunk and shoots of *P. nigra* and which, when grouped together, form veritable burrs on old trees. *Phyllocoptes populi* Nal. acts as a vector for leaf erinosis. Against mites and aphids phosphoric esters are the most effective materials.

Hemipters

Apart from a *Tingitidae*, *Monosteira unicostata* Mls., which attacks *Leuce* poplars, the *Homoptera* are the chief parasites on poplars. As has been mentioned at the beginning of this chapter, research is still needed on their biology, for it is possible that some of them may be active agents in the transmission of diseases.

Cicadidae

In this group, of primary concern are the *Aphrophora*, whose larvae cover the shoots with their spit and cause swellings on the bark by sucking, and the *Jassidae* of the genus *Idiocerus*, which are very abundant on *Salicaceae*. Both insects and larvae penetrate the shoots with their rostrum, and the females make deep slits in shoots with their terebra for oviposition. *Pediopsis nassata* Germar. also preys on poplars. *Tettigoniella viridis* L., which flourishes in moist grasslands, in some regions lays its eggs exclusively in the lower parts of woody species, particularly poplars, causing disintegration of the bark and necrosis of the wood.

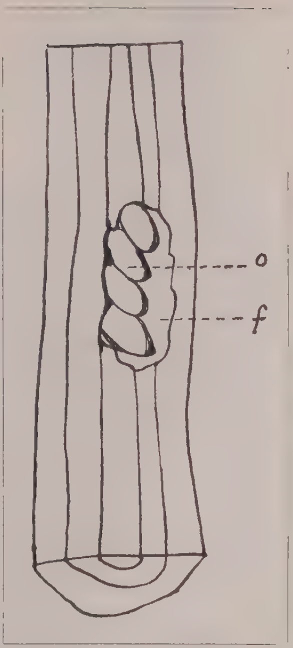


FIGURE 153. – Slit for egg-laying (*f*) containing eggs (*o*) of *Idiocerus populi* (x 4).

Courtesy *R. Régnier*

Aphididae

Among the aphids there are some leaf-eating species (*Chaitophorus*), and others, such as the large gray poplar aphis *Chaitophorus* (*Cladobius*) *populeus* Kalt., which form colonies on two- or three-year-old shoots. These insects suck the bark, which subsequently splits, the edges dry off and the appearance of cankers is not uncommon. Gall-forming aphids are not discussed here, since they have already been dealt with. There are numerous products on the market with a base of nicotine or phosphoric esters for destroying aphids in nurseries.

Of all aphids, the woolly poplar aphis, *Phloeomyzus passerinii* Sign., remains the most dangerous. Colonies of this insect may cover the trunks of large trees, causing dieback or even death outright. This aphid, which probably originated in Egypt, was introduced into the Po Valley in 1934 and has since caused considerable damage in Italy. It attaches itself preferably to the north side of the trunk and attacks clones having a smooth bark, showing a preference for dense stands rather than isolated trees. Several parthenogenetic generations succeed one another throughout the whole of the hot season, reaching a peak in July; the apterous form winters in crevices in the bark and on the roots. No secondary host plant is known in Europe. It attacks black poplars (*Aigeiros*). According to Vivani, *P.* x *euramericana* cv. 'robusta' and *P. deltoides* ssp. *angulata* are resistant to it. Certain clones have a varying degree of resistance: *P.* x *euramericana* cv. 'I-214' is not entirely immune, although highly resistant; 'I-455' is never attacked, and 'I-154' slightly vulnerable. Other clones, on the other hand, are very prone to attack. In theory, the aphid-killing products used against the woolly apple aphis (*Eriosoma lanigerum*) are effective.

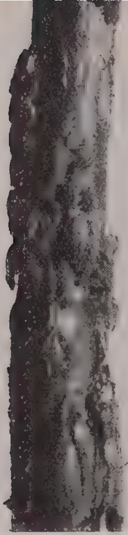


FIGURE 154. – *Chaitophorus populeus* (x 2).

Courtesy *R. Régnier*

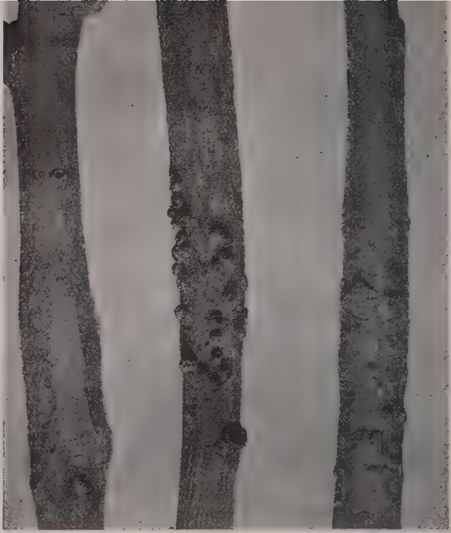


FIGURE 155. – Eruptions and swellings on bark caused by aphid infestation. Center: aphids parasitized by *Aphididae* (actual size).

Courtesy *R. Régnier*

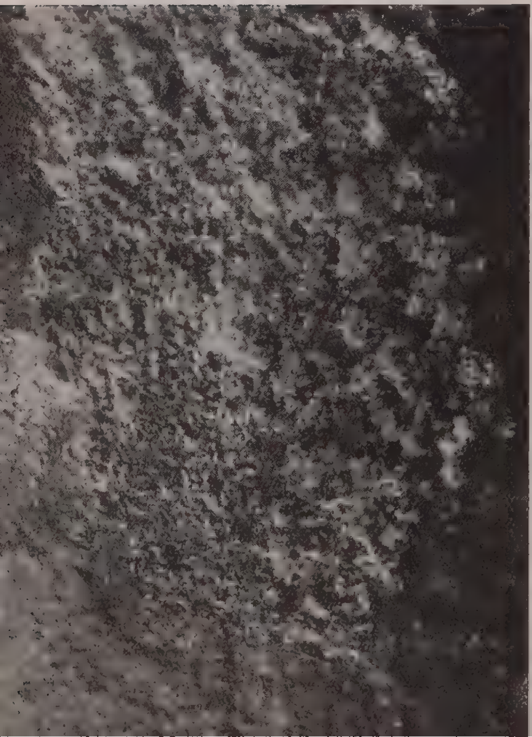


FIGURE 156. – *Phloeomyzus passerinii.* Woolly poplar aphis on a trunk (actual size).

Courtesy *Della Beffa*

Coccidae

The scaly varieties of the tribe *Diaspinae* are the most destructive. The aggregation of scales can be so thick as to cover the bark completely. This is the case for example with the willow coccid, *Chionaspis salicis* L. and the coccid *Lepidosaphes ulmi* L., which is highly injurious to fruit trees and which causes a hardening of the bark and the formation of stony nodules in the medullary rays of young stems and shoots. The tree is thus weakened and its growth rate arrested.

Poplars are also reported to be host plants of the mulberry coccid, *Aulacaspis* (*Diaspis*) *pentagona* Targ. and the deadly San José scale *Quadraspidiotus* (= *Aonidiella*) *perniciosus* Comst.

The isolated forms of globular scale, such as the *Lecanium* and the *Pulvinaria*, are on the whole rare.

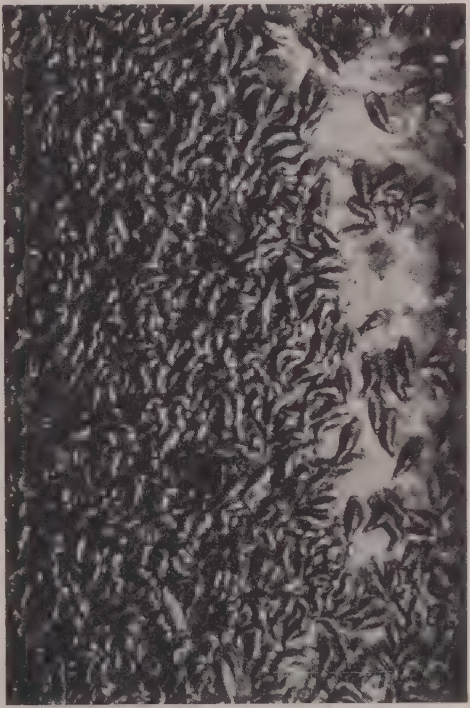


FIGURE 157. – *Lepidosaphes ulmi*.

Courtesy *W. Vivani*

Control measures

In order to prevent the spread of centers of infection, infested trees should be treated with a white winter oil (emulsion of mineral oil) or a yellow oil (with a dinitrocresol base) at 3 to 5 percent during the dormant season, or a white summer oil at 1 to 2 percent in June to destroy the young larvae.

Furthermore, care should be taken never to use cuttings from stock which is attacked.

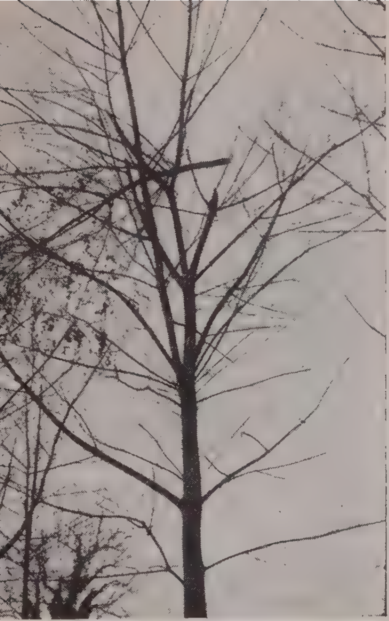
GENERAL IDENTIFICATION TABLE OF INSECTS INJURIOUS TO POPLARS

Attack of parts underground	
Cuttings and roots nibbled by white curved larvae with brown heads. Dieback of cuttings and plants	*Melolonthinae*, p. 283
Roots tunnelling with residual frass	*Capnodis*, p. 284
Attack of the wood (xylophagous larvae)	
External evidence of damage: exit holes, frass on the bark and often at the foot of the tree (in the case of the large species)	
Regular-shaped swellings on stems and shoots:	
with horseshoe scar on the bark	*Compsidia*, p. 286
without horseshoe scar	*Semasia*, p. 306
Swellings of irregular shape (plants and young trees):	
concentric scar left by occlusion of the exit hole	*Gryptorrhynchus*, p. 293 *Sciapteron*, p. 296
No swellings: attack of the trunk, particularly the lower part:	
foot	*Capnodis*, p. 284
lower part	*Saperda*, p. 288
up to 12 meters and above	*Trochilium*, p. 295
Fetid discharge, excreta irregular	*Cossus*, p. 298
Bark stripped from young shoots	*Capnodis*, p. 284
Ring-shaped occlusion scar	*Cimbex*, p. 299
Internal evidence of damage: tunnels	
Circular and median ascending; swellings; small slender larva, white, legless, with sharp mandibles	*Compsidia*, p. 286
Deep and sinuous, multiple attacks (young trees)	
Small curved larva, white, legless	*Cryptorrhynchus*, p. 293

Small white caterpillar with rudimentary legs	*Sciapteron*, p. 296
Straight central; large white caterpillar with black spots, legs well developed, excreta cylindrical	*Zeuzera*, p. 298
Broad, sinuous, deep, flat at the bottom; frass fine, large white larva, legless, broad anterior segment	*Capnodis*, p. 284
Broad, very sinuous; much frass, fetid, and tinted; large purplish-red caterpillar	*Cossus*, p. 298
Broad, deep, generally straight, often localized in the center of the tree; coarse frass, large white larva, legless, with dorsal and ventral protruberances	*Saperda*, p. 288
Deep sinuous; frass more regularly shaped, medium-sized caterpillar, white, with only rudimentary legs	*Trochilium*, p. 295
Small, sinuous, spiral, shallow beneath the bark; small white legless larva, broad anterior segment	*Agrilus*, p. 292
Sinuous tunnels in the cambium; very small slender larva, legless	*Agromyzidae*, p. 299

Attack of buds, young shoots and foliage (defoliators)

Young shoots gnawed by small caterpillars, often with silk threads	Leafroller moths, p. 306
Young shoots gnawed by weevils, without silk spinning	*Curculionidae*, p. 300
Leaves browsed, small larvae often found in colonies when young	*Chrysomelidae*, p. 301
Leaves nibbled round the edges	*Curculionidae*, p. 300
Leaves eaten irregularly:	
by caterpillars	*Lepidoptera*, p. 302
by cockchafers	*Melolonthidae*, p. 300
Leaves eaten regularly, attacked from beneath, false caterpillars found in colonies	*Tenthredinidae*, p. 307



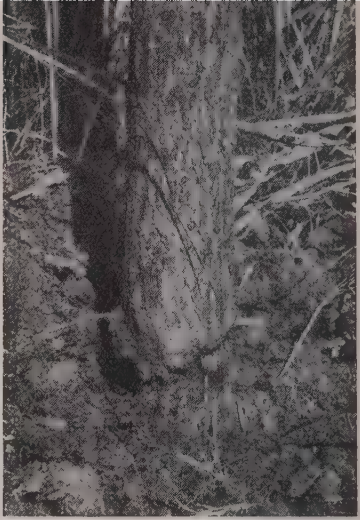


FIGURE 159. – Damage caused by water vole.

Courtesy *R. Régnier*

FIGURE 158. – Damage caused by squirrels in France.

Courtesy *R. Régnier*

FIGURE 160. – Damage caused by field mice.

Courtesy *R. Régnier*

Leaves rolled like cigars	*Rhynchites*, p. 300
Leaves mined (by larvae and caterpillars)	Poplar leafminers, p. 306
Buds, young shoots, leaves and petioles with characteristic distorsion	Gall wasps or gall midges, p. 307
Sucking insects	
Small slits in shoots and young stems: roving larvae	*Cicadina*, p. 279
Attack of young shoots, leaves and shoots, slitting of the bark	*Aphididae*, p. 311
Attack of the trunk by large colonies of woolly poplar aphis	*Phloeomyzus*, p. 311
Encrustation of the bark with colonies of small scales	*Coccidae*, p. 313

B. PROTECTION AGAINST RODENTS, GAME AND FARM ANIMALS

Young plantings are subject to attacks by small rodents, such as hares and rabbits, and must be protected against them.

There are two species of rodents which attack the roots and the collar of young trees exposing the base: the water vole, *Arvicola terrestris amphibius* L., and the field mouse, *Pitymys subterraneus* Sélys, which burrows deep. Trees which are attacked in this way are subject to windblow. The bank vole, *Evotomys glareolus* Schreber, climbs the trees and attacks buds and young shoots.

To prevent attacks from small redents it is advisable to keep the foot of the tree clear of herbage and plants which give them cover. Reproduction of these animals can be arrested by poisoned baits, chiefly of zinc phosphide, placed in drains or underplanks to avoid accidents to other animals. The water vole can be fairly easily trapped and is commonly found only on marshy land. Coating the base of the trunk with carbonyl or with a solution of lime and cow dung also prevents rodents from nibbling the bark.

Squirrels, particularly *Sciurus vulgaris* L., cause damage especially to medium-aged poplar stands in the vicinity of large woods and forests, and also to coppice with standards. The red squirrel attacks the upper part of the tree on a level with the highest crowns. It barks the leading

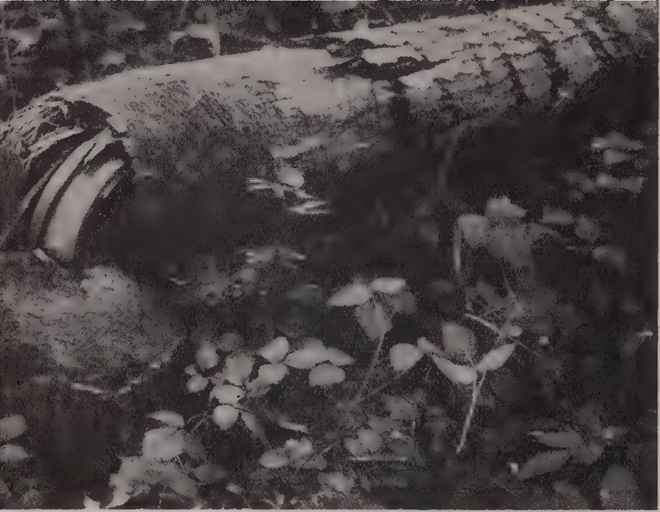
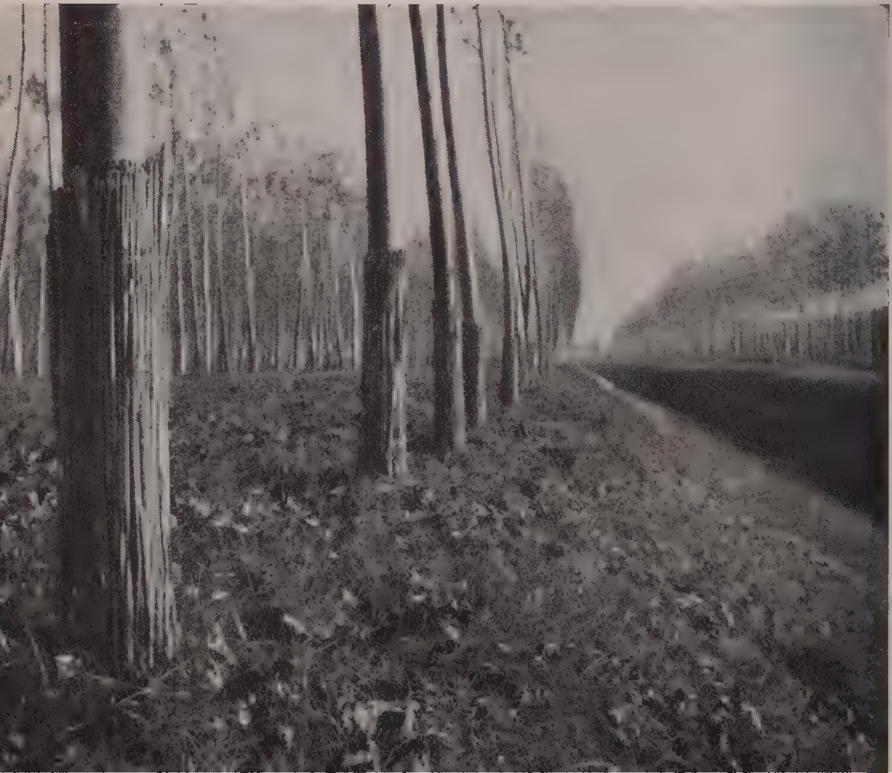


FIGURE 161. – *P.* 'robusta', 1 meter in circumference, felled by *Castor fiber* on the banks of the Rhône at Saulce, Drôme, France.

Courtesy *R. Rol*

FIGURE 162. – Poplars protected against hares and rabbits at Tor Viscosa, Udine, Italy.

Courtesy *G. Giordano*



shoot, tearing off a strip of bark 40 centimeters to 1.50 meters long, in fragments 6 to 12 centimeters long and 2 to 3 centimeters wide. It carries these off to its nest. The top of the tree subsequently dies back and snaps off at the first gust of wind. Squirrels are easily caught with break-back rat traps attached to the trunk by a wire at approximately 1.50 meters from the ground, and baited with grilled bacon or crushed apples rolled in lard.

Beavers damage *Salicaceae* in various ways. The dams built by *Castor canadensis* L. cause the water table to rise, producing stagnation, which kills aspens in Canada. To prevent flooding, officers of the Canadian Service of Hunting and Fishing are sometimes obliged to trap the beavers and transport them to other areas. Moreover, beavers are very fond of the young shoots and do not hesitate to fell trees of 1 to 1.50 meters in girth for the succulent shoots in the crown. This is also the case in the lower Rhône Valley, where *Castor fiber* L. often attacks black and white poplars. Planting should therefore be avoided on the banks of rivers where beavers are numerous.

The ondatra or muskrat, *Fiber zibethicus* L., of Canadian origin and introduced into Europe in 1905, burrows into the banks of rivers, causing the collapse of trees which have been planted on them. They are fairly easily netted and their fur is highly valued.

Hares and rabbits nibble the bark of young trees. The base can be effectively protected by sleeves of netting, branches of pine, bundles of thorny branches or small boards (waste from the sawmill) attached to the trunk, or again by coating the trunk with used motor oil or cow dung and paraffin.

Large game animals (deer) are harmful to forest stands of poplar; the large herbivorous animals are very fond of the bark of aspens and can cause serious damage. They also feed on poplar shoots and can be highly destructive in nurseries; their numbers should be kept down by hunting. Moreover, nurseries and regeneration areas should be enclosed with fences 1 to 1.20 meters high, surmounted by barbed wire up to 2 meters. Young trees can also be protected by enclosing them in wire sleeves or by binding them with branches 1 meter long cut from the crowns of freshly felled conifers.

Trees planted in pasture land should be protected against grazing animals, and wire sleeves or thorny branches are generally used for this purpose. Painting the trunks with a mixture of lime and cow dung gives protection against cows, and lime and horse dung against horses.

II. DISEASES OF POPLAR

At every stage in poplar cultivation, it is necessary to stress the importance of species, variety and even clone, for the behavior of poplars in relation to site, silvicultural treatment, pests and diseases varies from clone to clone. This aspect of the genus is particularly important insofar as diseases are concerned. In some cases the differences between clones, in their reaction to a particular disease, are so clearly defined as to provide the only measure necessary for control, i. e., the avoidance of susceptible clones. It is only when the large number of diseases to be dealt with are considered, and when it is understood that clonal susceptibility may be different in each case, that it is realized that few, if any, clones can be resistant to all diseases. All of which brings to the fore two other factors of distinct importance: first, the question of what still needs to be done in order to avoid further spread of diseases which are still limited; and secondly, the problem of research into methods of disease control not based on clonal resistance. These two points are elaborated in the following pages.

It is obviously impossible to describe all the diseases of poplar adequately in a single chapter; therefore, only the more important diseases can be included, and even these cannot be dealt with in great detail. In many countries of Europe there is at present much literature dealing with poplars and their cultivation, some containing sections on poplar diseases. The many papers on specific diseases, referred to in the bibliography, can be used as sources of additional information.

The principal diseases affecting poplars are discussed under two main headings: Diseases Caused by Inorganic (nonliving) Agencies; and Diseases Caused by Fungi and Bacteria.

A. DISEASES CAUSED BY INORGANIC AGENCIES

Poplars, as any other trees, are affected by a wide range of site factors. In fact, it is probably correct to classify poplar as a tree particularly sensitive to its environment. It is obviously difficult to indicate at precisely which point poor growth due to an unsuitable site actually becomes disease, and in practice no clear line can be drawn. The inorganic agencies considered here, however, are those which can cause severe checks in growth or actual death of leaves, branches or roots.

Wind

Despite the fact that poplars, in particular *P. nigra* cv. 'italica', are often planted for shelterbelts, it is generally agreed that they do suffer severely if constantly exposed to high winds. For this very reason, in the northeastern part of the Netherlands for example, poplar is rarely used as a roadside tree. *P. alba*, on the other hand, is much more resistant to wind, and even to salt spray, so that this species is valuable for seaside shelterbelts. This resistant quality to sea winds is present, in all probability to a lesser exent, in *P. canescens*, and there is some evidence that *P. tremula* is more resistant to wind blast than the black hybrids; *P.* x *euramericana* cv. 'robusta' is considered highly susceptible.

Little information is available, however, on varietal resistance to wind, so that, among the black and balsam poplars, no precise recommendations can be made for planting on highly exposed sites. Most poplars appear able, however, to withstand winds encountered at low elevations, inland. Some varieties, such as *P.* x *euramericana* cv. 'serotina', lean very markedly away from the prevailing winds. This has little effect on the straightness of the stem but leads to the production of compression wood and subsequent difficulties in procuring an even rotary veneer. Further information on clonal behavior with regard to this type of wind distortion would be very valuable.

Actual breaking of the limbs from wind normally occurs only in older trees, which have formed the heavy spreading crowns typical of poplars over 50 years of age. At this stage in its life poplar cannot be regarded as a safe tree. For this reason, roadside poplars should not be left to an old age. A few of the large-leaved varieties, notably *P.* x 'generosa', are apt to break in the crown when 15 years old or over, presumably because of the wind resistance of the lush foliage. In the trials of Italian selections at Casale Monferrato some clones have shown a tendency to bend over in gales and never resume a vertical position. This would appear to indicate a structural weakness of the wood and must obviously lead to the rejection of the clones affected. None of the older clones in general used for timber production appear to suffer from this weakness except when badly underthinned, when their stems are overtall in relation to their diameter.

Salt

The matter of salt spray, borne by the wind, has already been dealt with. Recent experience in the Netherlands, following the disastrous North Sea floods of January 1953, has shown that the same two species, *P. alba* and *P.* x *canescens*, are fairly resistant to salt in the soil, whereas the hybrid black poplars (*P.* x *euramericana*) are among the most susceptible. This experience with sea-flooded land is probably a guide to the behavior of poplars on permanently saline sites. *P. euphratica* occurs naturally in places on soils with a high salt content.

Frost

Despite the fact that it is generally limited to the northern temperate regions, the genus *Populus* does grow in a number of widely different climates. It is natural, therefore, when poplars are grown out of their natural climatic environment in colder regions, to expect injury from frost. Winter injury to buds and twigs is nevertheless quite rare and normally only occurs on southern varieties grown in colder northerly climates; for instance, some forms of *P. deltoides* from the extreme south of the United States, or *P. yunnanensis* from China when planted in northern Europe. Certain other varieties, normally inhabiting areas with continuously cold continental winters, come into leaf too early under oceanic conditions and are frosted in early spring. This is the case with *P. koreana* and its hybrids when planted in Great Britain. Apart from these very early flushing types, however, there is no direct relation between date of flushing and frost injury in the spring. Some other varieties, adapted to a long growing season, may continue growth too long into the autumn, when planted in countries with a shorter summer, and may be cut back by autumn frost while the young growth is still unripened. This is the case with some of the Italian (Casale Monferrato) selections, when grown in Great Britain.

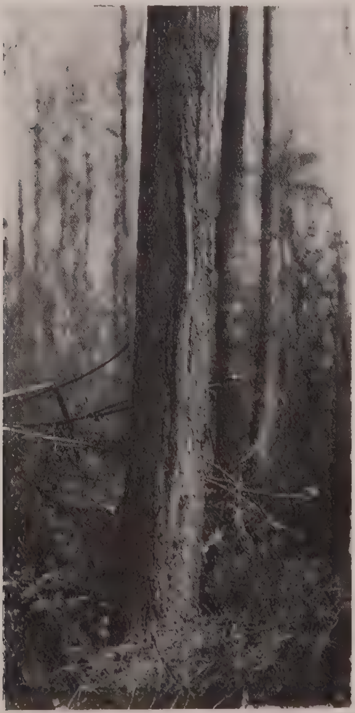


FIGURE 163. – Frost crack on *P.* x *euramericana* 'regenerata', in Belgium.

Courtesy *Forestry Commission*

Defoliation by leaf disease, and in

particular by *Melampsora* rusts, apparently stops the proper ripening of the leafless shoots. As a result, they remain frost-susceptible and often die back, following the first autumn frosts.

Damage due to spring and autumn frosts usually takes the form of withering of foliage and dieback of the ends of the shoots. Cankers may also be caused, particularly on young trees near ground or vegetation level. These cankers may subsequently be colonized by fungi such as *Dothichiza populea* or *Cytospora chrysosperma*, and their true origin thus hidden. Owing to the very varying conditions of climate in different countries, data on frost injury to poplars collected in one area are unlikely to have a very wide application elsewhere. For this reason none of the available data on varietal frost susceptibility, which in any case are very meager in quantity, are quoted here.

Poplars are, unfortunately, one of the trees liable to frost-crack in the winter. This is apparently due to unequal expansion and contraction of the wood on freezing and thawing, and occurs most frequently on the south side of the tree, where alterations of temperature are most rapid. The cracks extend deep into the wood, making it useless for veneer peeling. During the summer the efforts of the tree to heal the crack result in a ridge of tissue above the crack, and it is by this raised strip of bark that frost-crack is most readily detected. It occurs only, of course, in countries with cold winters, and even there not sufficiently frequently for any information to be available on varietal susceptibility.

Water relations

Despite their liking for abundant soil moisture, poplars will grow, though perhaps slowly, on surprisingly dry soils once they are established. *Populus deltoides* has been used as one constituent of shelterbelts in the dry regions of the midwestern United States. Only on extremely dry or extremely wet sites is poplar cultivation impossible. Temporary drought on otherwise suitable sites can, however, be very damaging, especially if the trees are not fully established and still have insufficiently developed root systems. It is generally admitted that drought, following planting, is one of the chief predisposing factors to attack by the fungus *Dothichiza populea*. In some cases soil water may be sufficient for the trees when young but may prove inadequate when they become larger.

Little information is available on the drought resistance of different varieties but there is evidence that poplars normally adjusted to woodland conditions, such as *P.* x *canescens* and *P. tremula*, are more resistant to

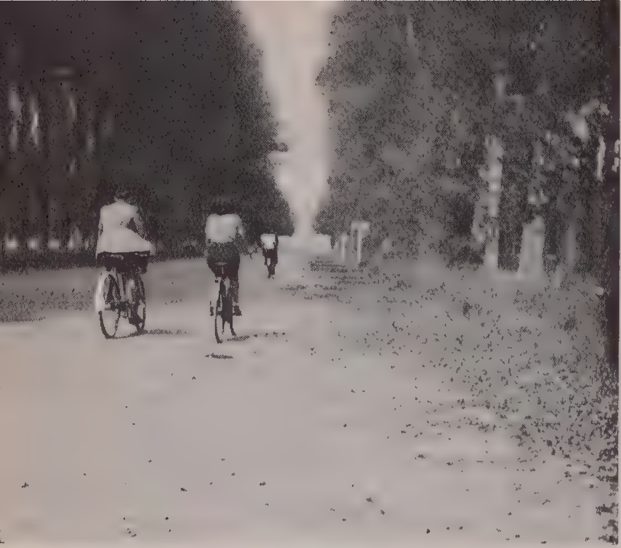


FIGURE 164. – *P. nigra* 'italica', which were defoliated in the spring of 1951 by *Venturia*, at Stupinigi, near Turin.

Courtesy *G. Piccarolo*

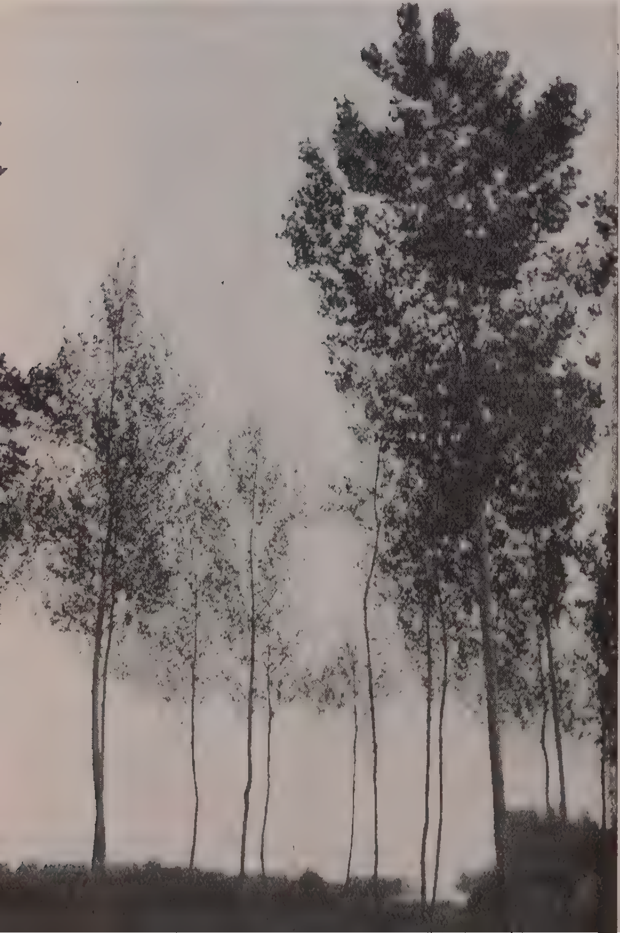


FIGURE 165. – Spring defoliation of poplars by *Venturia*, at Stagno Lombardo, near Cremona, Italy. Right: resistant trees.

Courtesy *G. Piccarolo*

drought than those which are normally riverside trees, such as *P. nigra* or *P. deltoides*.

On the question of excess of water, it can confidently be stated that poplars are unaffected by flooding, even for periods of several weeks. The greater the movement of the water, the longer the flooding can continue without damage to the roots. Immersion in completely stagnant water, however, can cause serious injury, if it continues for more than a few weeks.

Sun scorch

Young poplars, having comparatively thin bark, are occasionally subject to sun scorch. Patches of bark on the exposed side of the tree are killed, leading to canker and to subsequent decay. Poplars which have always grown under open conditions are not likely to be affected, but closed plantations heavily thinned, or trees suddenly exposed to the sun by the felling of neighboring trees, often show this form of injury.

Deficiency diseases

It is well known that poplars are rather demanding as regards soil nutrients, and their reaction to poor soils, and particularly to acid soils, might also be regarded as coming under the heading of disease. Their requirements of trace elements are not known, but chlorosis (yellowing and mottling of the foliage) occurs sufficiently commonly to suggest that their requirements are not always met by the soils in which they are grown.

Smoke and fumes

Poplars are generally regarded as resistant to smoke and fumes, and may frequently be observed growing in or near industrial towns. Unfortunately, their rapid growth, eventual large size, and the damaging effect of their roots on buildings, limit their usefulness in such situations. No information is available to indicate any difference between varieties in their tolerance to smoke and fumes.

B. Diseases caused by fungi and bacteria

An enormous number of fungi have been reported on poplar but only those having a definite pathological significance are dealt with below. They are discussed under four headings, according to the part of the tree affected. When, as occasionally happens, a fungus attacks several parts of the tree, it is discussed under that part on which it causes most injury.

It should be noted that only the most obvious symptoms of the diseases dealt with are described. No details are given of the fruit bodies and microscopical structure, or of the systematic position of the fungi concerned. It is considered that such detail would be of interest only to the mycologist, and therefore out of place in a publication intended primarily for those concerned with poplar from a strictly practical angle.

LEAVES AND SUCCULENT SHOOTS

Spring defoliation (*Venturia*)

In Italy, and to a lesser extent in other parts of Europe, poplars are subject to very severe spring defoliation and withering of shoots due to fungi of the genus *Venturia.* It appears that two fungi are concerned, *V. populina* (Vuill.) Fabr. (*Endostigme populina* [Vuill.] Cif., etc.), of which the imperfect stage is *Pollaccia elegans* Servazzi on hybrid black poplars, and *V. tremulae* Aderhold, of which the imperfect stage is *Pollaccia radiosa* (Lib.) Bald. and Cif. (*Fusicladium radiosum* [Libert] Lind, etc.) on aspen. It will be realized from the synonyms given above, which are only a small selection from the large number that have been used, that there is considerable confusion over the nomenclature of these fungi. Several names have been used indiscriminately for both fungi, so that it is scarcely possible to deal with them individually.

They both cause the same type of injury, the young leaves and succulent shoots withering and blackening in the spring. Complete defoliation may result from heavy attacks. High atmospheric humidity favors the fungus, and in hot dry summers the disease soon becomes quiescent. The fungus fruits inconspicuously on the weathered leaves and shoots.

Venturia has been recorded in the Netherlands, Denmark, Germany, Finland, Great Britain and the United States, and is doubtless present elsewhere; but only in Italy is it normally referred to as a serious cause of loss, and most of the rather considerable literature on the disease is Italian.

Some information is available on resistance and susceptibility. In Italy, *P. nigra*, *P. nigra* cv. ' italica ', *P. alba* and *P. tremula* are seldom attacked, whereas some forms of *P.* x *euramericana* are susceptible. However, *P.* ' I-214 ' and some of the other Italian selections are highly resistant. On the other hand, in northern Europe this fungus (probably *V. tremulae*) appears to be restricted to *P. tremula*, and it has been noted that hybrid aspen (*P. tremula* x *tremuloides*) is resistant. It is possible therefore that *Venturia populina* is not present in northern Europe.

Control of a disease of this kind is obviously difficult but in view of the resistance of some of the Italian selections, breeding and selection would appear to be a possible line of action.

Phyllosticta - Withering or dieback

Somewhat similar damage to that due to *Venturia* is caused by the fungus *Phyllosticta populina* Sacc. Its distribution is not known but it has been recorded in Great Britain, chiefly on balsam poplars and their hybrids, while in Italy it is reported to do serious damage to young plants when the weather conditions favor attack.

Pestalozzia - Shoot disease

A disease of young poplar shoots caused by the fungus *Pestalozzia populi-nigrae* Sawada and Ito, has been reported from Japan on *P. nigra*, *P. nigra* cv. ' italica ', and *P. deltoides* ' monilifera '. The fungus spreads rapidly on the shoots of the current year, often girdling them. The lesions first appear as well-defined brown areas, and a conspicuous symptom of the disease by mid-June is the presence of one or more dead leaves on the affected shoots. Later the affected areas turn pale brown and the small erumpent fruit bodies are produced. At a later stage some canker formation may take place of shoots that are not girdled. On inoculation, *P. simonii* has proved moderately susceptible and *P. maximowiczii* resistant.

Marssonina - Leaf spot

This fungus causes only a leaf spot on poplar but can result in a certain amount of defoliation. The blackening of the leaves starts between the veins, and the fruit bodies of the fungus, very small pustules visible only with a lens, are produced on these withered areas.

A number of species and forms have been distinguished (*M. populi-nigrae*. Laub., *M. populi albae* Laub., and *M. tremuloides*). *M. populi* has been reported from Germany, the Netherlands, Italy, Great Britain and Iran. *M. tremuloides* is said to be capable of reaching epidemic proportions on aspen in Alberta, and is also prevalent in parts of the United States. Both fungi almost certainly have wider distributions but are probably seldom serious causes of loss.

Though there are known to be marked variations in attack on different varieties of poplar, no detailed or accurate information on varietal resistance is available.

Septotinia - *Leaf blotch*

The fungus *Septotinia populiperda* Waterman and Cash, has been reported in the United States, in Germany and in the Netherlands. In America it has caused extensive defoliation on a number of hybrid poplars, but in the Netherlands, although it has attacked several varieties, including *P. candicans*, *P.* 'serotina', *P.* 'robusta' and *P.* 'gelrica', it is not regarded as serious.

The blotches on the leaves, starting in early spring as small brown spots, develop rapidly. Before long, white masses of spores are found on both surfaces of the leaves: on the upper surface they tend to develop in concentric circles.

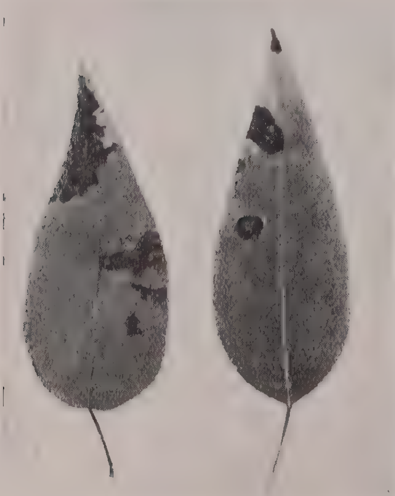


FIGURE 166. – Leaf spot caused by *Septoria musiva*.

Courtesy *U. S. Forest Service*

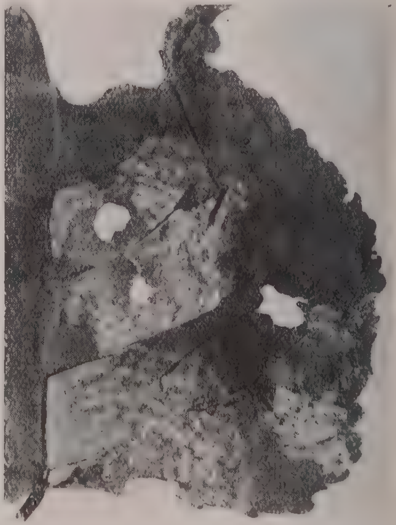


FIGURE 167. – Leaf pustules caused by *Septotinia populiperda*.

Courtesy *U. S. Forest Service*

Septoria - *Leaf spot*

Three species of the genus *Septoria* are associated with leaf spot on poplar. *S. musiva* Peck. is much more serious as a cause of stem canker and dieback, and in that guise is dealt with later. As a cause of damage to leaves it is of much less account, but appreciable loss of foliage, mainly of the lower leaves, can take place. The individual lesions on the leaves may be circular or angular and are brown with cream-colored centers. As a cause of leaf spot it occurs in Canada on *P. tacamahaca*, *P. tremuloides*, *P. candicans* and *P. trichocarpa*. It has not, so far, been found in Europe.

A much less important leaf spot, with a much more restricted host range, caused by *Septoria populicola* Peck., the perfect stage of which is *Mycosphaerella populicola* Thompson, has been described in America. This also has not been reported from Europe.

A third species, *S. populi* Desmaz., the perfect stage of which is *Mycosphaerella populi* (Auersw.) Klebahn, has been recorded in the U.S.S.R., Spain, Italy, Iran and the Argentine. It does not seem to be particularly damaging but the very incomplete information available suggests quite a wide host range. Perhaps its most disquieting aspect is that a chance introduction of the much more serious fungus *S. musiva*, might at first, until it spread to the stems, be mistaken for this fungus, so that *S. musiva* might become established before its serious significance had been realized.

Leaf blister

This very striking disease is caused by the fungus *Taphrina aurea* (Pers.) Fries. This disease appears to have a very wide distribution but is seldom regarded as a source of real damage. Early in the summer the leaves become distorted with large blister-like excresences. The spores are produced on the concave side of these blisters, which are on the underside of the leaf, and are orange in color. These orange patches are very conspicuous and are sometimes mistaken for the rust fungus, *Melampsora*, the symptoms of which are, in fact, quite different. The disease seldom leads to leaf fall, so that it is more conspicuous than damaging.

The fungus appears to be able to attack most varieties of poplar but is most commonly met with on forms of *P.* x *euramericana*.

Melampsora - Rust

By far the commonest, most serious and most widely distributed leaf disease of poplars is the rust caused by species of the genus *Melampsora.* When poplars are attacked by these fungi the undersurface of the leaves becomes thickly covered with small bright orange-yellow fruit bodies, which appear from mid-summer onward. In the case of a heavy attack, the infected leaves wither and fall prematurely, and this often results in a reduction of growth. In climates where autumn frosts occur, secondary damage may result, because the defoliated shoots fail to ripen properly and are cut back by frost.

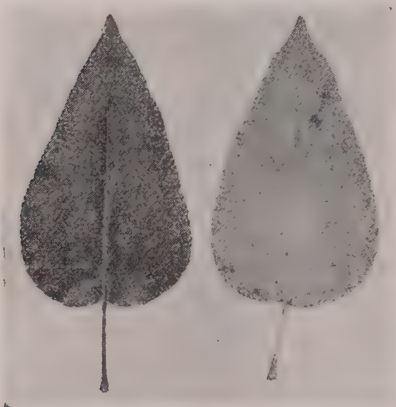


FIGURE 168. – *Melampsora* rust on leaves of *P. trichocarpa,* in the United Kingdom.

Courtesy *Forestry Commission*

A considerable number of species of *Melampsora* are concerned, but since they all appear similar on the leaves of poplar, it is necessary to consider them together. Like many other rusts, they have two host plants, spending part of their life on poplar and part on the other. Their classification is to some extent dependent on the hosts on which they occur.

It must be admitted that the information available on the poplar hosts of the American rusts is rather vague and suggests that there may have been some confusion between the different rusts.

The distributions given in Table 11 are probably far from accurate, but complete data, as with most fungal diseases of trees, are not available. It is obvious that different rusts occur in different parts of the world, and that they can move or be moved from place to place, since several rusts are now present in the Argentine, where poplar is an introduced tree. It is also noteworthy that there has apparently been a transference of European rust species to America and vice versa. It is necessary here to stress the word "apparently." The *Melampsora* species are so similar on the poplar host, and generally so inconspicuous on the alternate host, that a new rust might become well established in one or other continent, before it was realized that it was different from the native rusts. The principal species of rusts are given in the following list:

TABLE 11. – PRINCIPAL SPECIES OF RUSTS

Species	Alternate host	Poplar host	Distribution
M. magnusiana Wagner	*Fumaria* spp., *Cordalis* spp., etc.	Aspen and white poplars	Japan
M. occidentalis Jacks	Unknown	Black and balsam poplars	North America
M. pinitorqua Rostrup	*Pinus* spp.	Aspen and white poplars	Europe Near East
M. rostrupii Wagner	*Mercurialis perennis*	Aspen and white poplars	Europe
M. abietis-canadensis (Farl.) Ludwig	*Tsuga* spp.	Aspen and balsam poplars	North America
M. albertensis Arthur	*Pseudotsuga taxifolia*	Aspen and balsam poplars	North America Argentina
M. allii-populina Klebahn	*Allium* spp.	Black and balsam poplars	Europe Near East, North Africa Argentine
M. larici-populina Klebahn	*Larix decidua*	Black and balsam poplars	Europe Near East Argentine
M. larici-tremulae Klebahn	*Larix decidua*	Aspen and white poplars	Europe
M. medusae Arthur	*Larix* spp.	Aspen and black and balsam poplars	North America France

It may be asked why, if they are so similar on poplar, it is necessary for the poplar cultivator to distinguish species at all. The answer lies in the question of varietal resistance. The above list indicates that certain species are confined to aspen and white poplars (Section *Leuce*) and others to the black and balsam poplars (Sections *Aigeiros* and *Tacamahaca*). Inside these groups there are undoubtedly variations in varietal resistance to the different species of *Melampsora*.

In practice, of course, the data collected on varietal resistance in any one country tend to refer to all the rust species occurring in that country, with a bias in favor of those occurring most commonly. But if a new rust were introduced, it might have different varietal preferences and cause serious damage to types hitherto regarded as resistant. The position is further complicated by the knowledge that variation within the *Melampsora* species is possible, and even that hybridization between species may occur. This means that new forms may arise with different varietal preferences, as has happened with some of the rust fungi on wheat, necessitating continuous breeding of wheat varieties resistant to new variants of the rust. Such rapid production of new varieties and replacement of old would, of course, not be possible in the case of poplar.

Many of these rusts can maintain themselves on poplar without the intervention of the alternate host. The warmer the winter climate, the more likely this is to occur. It is almost certain that this occurs in the Argentine. In any case, since the spores first produced on poplar leaves in the summer are of a type capable of infecting other poplar leaves, a serious attack on poplar can develop from a small primary infection. Certainly, in most cases, it does not require a large concentration of the alternate host to promote a severe attack on poplar, and it could not be reckoned that removal of the alternate host from the vicinity of the poplars, even if that were possible, would stop the disease.

It has already been pointed out that in any one country data on varietal resistance generally refer to all the rusts occurring in that country, with particular emphasis on the common ones. In Great Britain, for instance, data would refer particularly to *M. larici populina*. For this reason, information collected in one country will not necessarily be applicable to another. Certainly, each continent, and probably each country, must test for itself the resistance to the local rusts of those varieties of poplar it desires to grow.

In Great Britain there is a tendency for balsam poplars and hybrids between balsam and black poplars to be more rust-susceptible than the hybrid black poplars, but this is not an invariable rule. For instance, while some clones of *P. trichocarpa* together with *P.* x *generosa* and *P.* x cv. ' McKee ', both hybrids of *P. trichocarpa* and *P. deltoides* ' angulata ' are highly susceptible, other clones of *P. trichocarpa* and some of the balsam hybrids of Stout and Schreiner are completely resistant. On the other hand, while most clones of *P.* x *euramericana* cv. ' robusta ' and *P.* x *euramericana* cv. ' serotina ' are moderately susceptible, *P.* x *euramericana* cv. ' eugenei ' is generally resistant. In America the degree of defoliation caused by *M. medusae* on different clones of *P. deltoides* has been found to range from 6 to 98 percent.

Control of these diseases must rest primarily on selection of resistant clones for cultivation. Spraying with Bordeaux mixture several times during the summer has been proved to lessen the severity of attack. However, spraying, even in the nursery, is expensive, and while more effective sprays could no doubt be found by experiment, it is still doubtful whether the improved growth resulting from the absence of rust would justify the cost.

Melampsora pinitorqua is the only one of the poplar rusts which causes more damage to the alternate host than to poplar. When *Pinus sylvestris* is planted near *Populus tremula* it is liable to be severely distorted by this fungus. The newly emerged shoots of the pine are affected, sometimes being girdled, and sometimes merely twisted by the unequal growth resulting from the death of one side of the elongating shoot. The pine is seldom killed but forked or distorted leaders and serious delays in growth often result.

In Cyprus, it occurs on *Pinus halepensis*; in Italy, on *P. pinea*, *P. pinaster* and *P. sylvestris*; and in France, on *P. pinaster*. It has also been recorded on *P. montana*. *Populus nigra* var. *calabrica* appears to be highly resistant, so that by using this species, pine can still be planted in the vicinity of *Populus tremula*.

TWIGS, BRANCHES AND TRUNKS

Weeping canker

A few years ago, bacterial canker (weeping canker) was regarded as the most important disease of poplars in northern Europe. Sanitation measures in the extremely affected countries, and the discovery that many of the poplars most commonly planted are resistant, has certainly lessened its importance. It is still, however, a source of loss in existing plantations in some countries and a potential threat to all newly introduced poplar clones. No clone can be adopted for general use until its susceptibility has been tested.

Most of the early work on the disease was carried out in France. It is now known that disease is caused by the bacterium *Pseudomonas syringae* fm. *populae* (Van Hall) Sabet, though other bacteria and fungi, including *Nectria*, may be concerned with the subsequent extension of the cankers. Inoculations with pure cultures of the bacterium failed to cause canker formation, whereas inoculations with the slime, which exudes in the spring, were successful. This led to the belief that other bacteria present in the slime were playing a part in the initiation of the disease. It has now been found that the bacterium, in the presence of a sterile filtrate of the slime, can cause cankers, and it therefore appears that the slime plays the role of a chemical stimulator.

Actually there is little evidence to favor the idea that bacterial canker is affected by the environment in which the poplars are growing. Serious outbreaks of canker have been recorded in almost all the conditions under which poplar can be grown. Quite certainly the disease cannot be avoided by any choice of site, or special cultural practice.

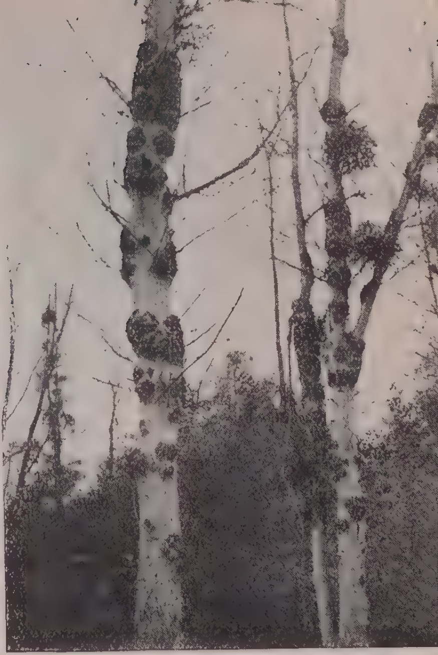
As far as is known, the disease is restricted to northwestern Europe (Germany, Belgium, the Netherlands, northern France and Great Britain). It has not been reported from America. It is possible that climatic conditions may be responsible for the very clear line of demarcation in France, south of which the disease does not occur. Even if this limit is due to climate, it could of course be affecting either the bacterium or some insect carrier responsible for its spread.

The cankers have been well described and illustrated in several publications, so that only a brief description need be given here. The first signs of the disease are small cracks in the bark of young twigs, from which in the spring, pale brown bacterial slime exudes. It is possible to produce canker on susceptible poplars by inoculating wounds with this slime. Sometimes the affected twigs are girdled and die back but often, as the twig grows, it tries to heal over the diseased area, and thus canker formation starts. It is these repeated efforts on the part of the tree to heal the wound, and repeated extensions of the wound by bacteria and probably later by other fungi, that give rise to the irregular, erumpent cankers, which are characteristic of this disease. Once a tree is infected, the bacterium appears to be able to spread internally, giving rise to fresh cankers, often on stems too old for external infection, and even on the main stem itself. As the disease progresses, cankers may spread and girdle quite large limbs, or even the trunk itself, so that a diseased tree is distinguished not only by the numerous cankers but also by a greater or lesser number of dead branches and twigs. The disease occasionally kills the tree but more often merely cripples its growth. Cankers on the main stem, of course, greatly lessen its utilization value. The disease usually attacks poplars from 10 years old upward. Younger trees are very occasionally attacked. It does not occur in nurseries.

The means by which the bacteria move from tree to tree are not known, though insect carriage is most probable. Artificially infected

FIGURE 169. – Weeping canker on poplar in France.

Courtesy *R. Régnier*



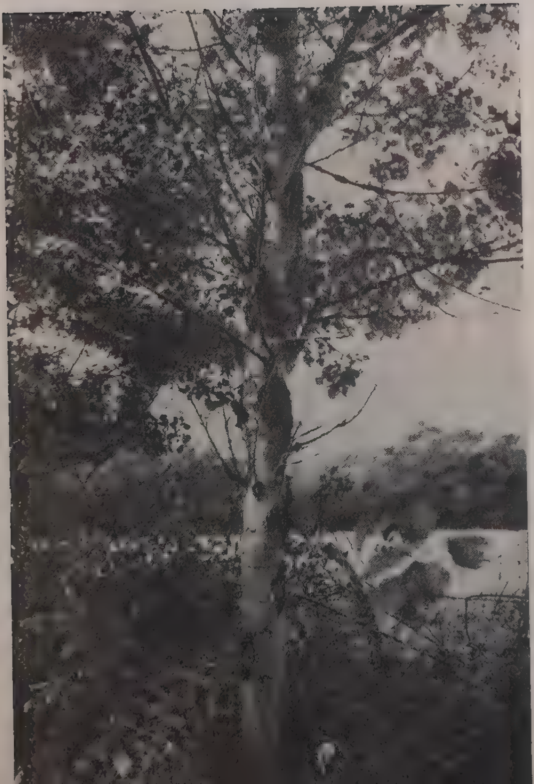


FIGURE 170. – Weeping canker (*Pseudomonas syringae* fm. *populae*) on *P.* x *euramericana* 'brabantica', in Western Germany.

Courtesy *Forestry Commission*

aphids and other insects have been proved capable of carrying the disease. Further knowledge of the mechanism of transmission might well help to explain differences in resistance and susceptibility, which are discussed below.

No cure is known for this disease. The best method of control is by the use of resistant varieties; nevertheless, cankered trees should be felled as a measure of sanitation.

Considerable work has been done in France and the Netherlands on testing resistance and susceptibility by artificial inoculation. More recently, similar work, as yet unpublished, has been carried out in Great Britain. There is, of course, some risk in applying results of this kind to field practice. It seems probable, however, that any poplar which is not highly susceptible to inoculation can safely be used for planting under normal conditions. For instance, *P.* x *euramericana* cv. 'robusta', which is moderately susceptible to inoculation, is seldom cankered in the field.

No attempt will be made here to give a list of susceptible or resistant varieties. Resistance varies so inexplicably from clone to clone that incomplete lists may be seriously misleading. It can be stated, however, that most of the commonly planted black hybrids, e. g., *P.* x *euramericana* cv. 'serotina', cv. 'robusta', cv. 'gelrica', cv. 'marilandica' and most of the Italian black hybrid selections are reasonably resistant. Certain clones of *P.* x *euramericana* cv. 'regenerata' are susceptible, others probably resistant. One clone of *P.* x *euramericana* cv. 'eugenei' is certainly resistant. Indeed, the highly susceptible poplar, which for a long time passed under this name in Great Britain, is now regarded as quite distinct and will be called *P.* x *euramericana* cv. 'pseudoeugenei'. Additional information on the resistance and susceptibility of the black hybrids is given in the chapter on the classification and identification of poplars.

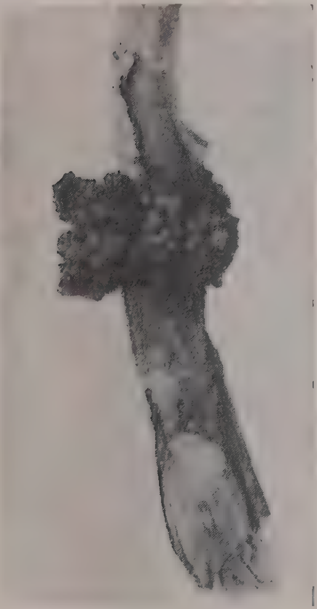
P. nigra and its varieties are very resistant but the status of the American black poplar, *P. deltoides*, has not been explored.

Many of the balsam poplars are highly susceptible but highly resistant clones of *P. trichocarpa* and *P. tacamahaca* x *trichocarpa* have been found.

P. alba and *P.* x *canescens* so far appear resistant, but *P. alba* cv. 'pyramidalis' (x *P. bolleana*) is known to be susceptible. *P. tremula* is occasionally found attacked in nature. It is almost certain that variations in susceptibility will be found in such a widespread species. Preliminary tests have indicated extreme susceptibility in *P. tremula* x *tremuloides*, an otherwise extremely valuable hybrid.

FIGURE 171. – Local form of bacterial canker on *P. nigra*, in Cyprus. This form is very different from the weeping canker found in Europe.

Courtesy *R. J. Streets*



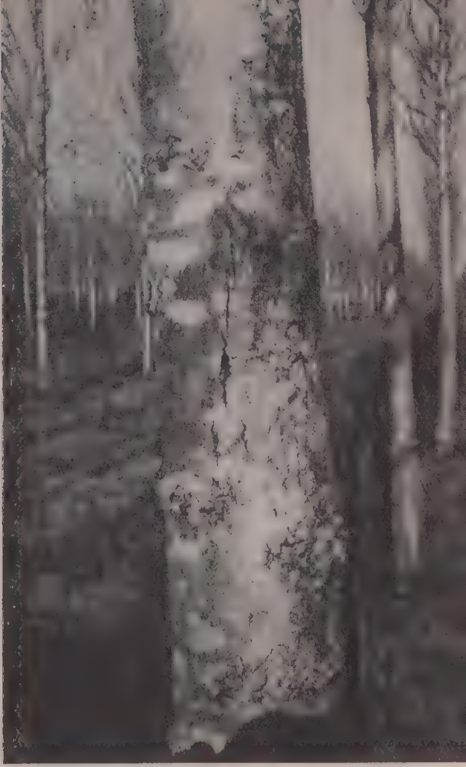
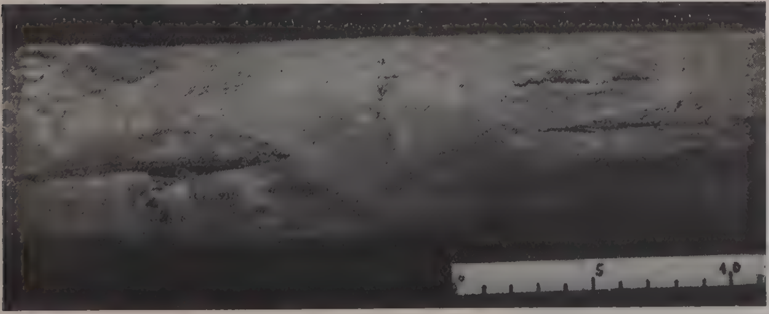


FIGURE 172. – "Brown spot" disease on 14-year-old *P.* 'robusta' on the Chautagne marsh, Savoy, France.

Courtesy *R. Rol*

FIGURE 173. – "Brown spot" disease on *P.* 'robusta'.

Courtesy *R. Rol*



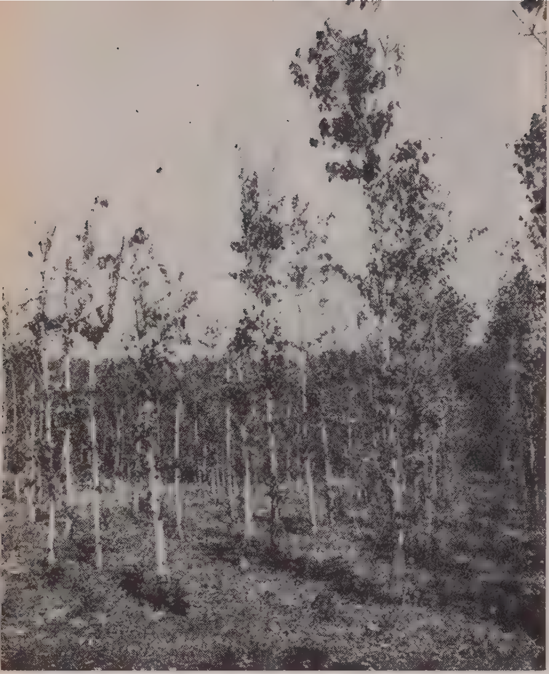


FIGURE 174. – Hybrid balsam poplars attacked by canker caused by *Septoria musiva*, at the McKee Nursery, Saratoga, New York.

Courtesy *R. Rol*

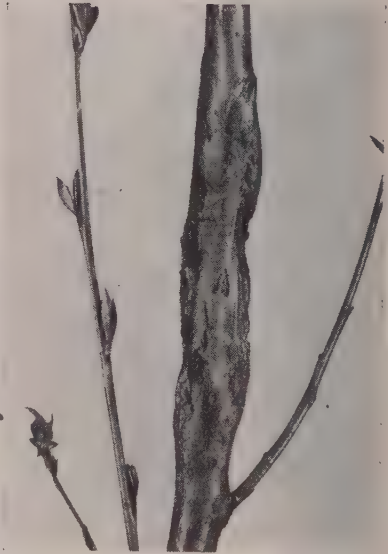


FIGURE 175. – Canker caused by *Septoria musiva* on a hybrid poplar shoot (*P. laurifolia* x *nigra*).

Courtesy *U. S. Forest Service*

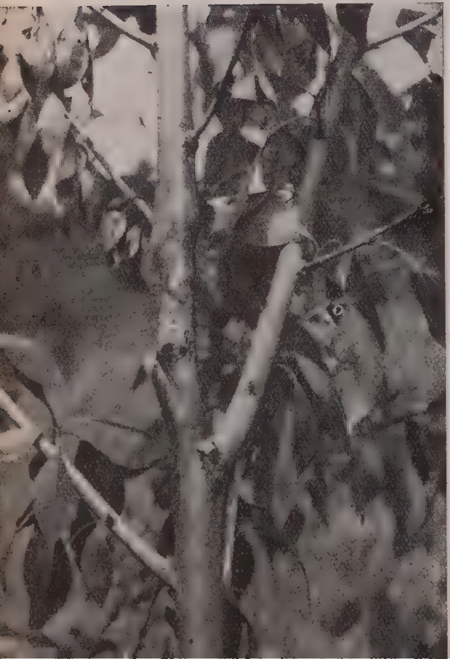


FIGURE 176. – Canker caused by *Septoria musiva* on a 5-year-old stem.

Courtesy *Canadian Department of Agriculture*

The final test must always consist in planting the clone in conditions of natural infection. Until this has been done, which will of course take time, there will be a strong element of uncertainty in the use of any new clone for commercial planting.

Other bacterial diseases

Bacterial cankers reported from southern Europe and the Near East are probably of different origin. In Cyprus and Syria, for instance, round tumors, suggestive of *Pseudomonas tumefaciens*, the crown gall organism, occur on the branches; while in Italy and in the south of France small short-lived, rather superficial bacterial lesions occur on certain clones (in France, particularly on *P.* ' robusta '). Although largely superficial, these bacterial infections leave small, dark inclusions in the wood, which greatly lessen its value for veneering. This disease is known as " brown spot. "

Nectria canker

A number of species of *Nectria* have been recorded on poplars but it would appear that *N. coccinea* (Pers.) Fries. is the commonest. *Nectria* is often found on cankers initiated by bacteria but it is probably capable of initiating cankers on its own on occasion. It is easily recognized by the bright red pinhead-sized fructifications. It certainly ranks only as a very minor cause of canker and dieback in poplars.

P. nigra and its varieties are said to be very susceptible to *Nectria coccinea*, so it is possible that this fungus may be one of the agents associated with the very common and unexplained dieback of *P. nigra* cv. ' italica '.

Septoria canker

Potentially one of the most serious stem diseases of poplar is the canker and dieback caused by *Septoria musiva* Peck., which occurs quite widely in the United States and Canada. The perfect (ascospore) stage of this fungus is *Mycosphaerella populorum* Thompson. It is normally a leaf fungus producing negligible damage to native American poplars but has caused severe injury to hybrid poplars, especially those of the *P.* x ' berolinensis ' group. It has also been reported causing canker on some

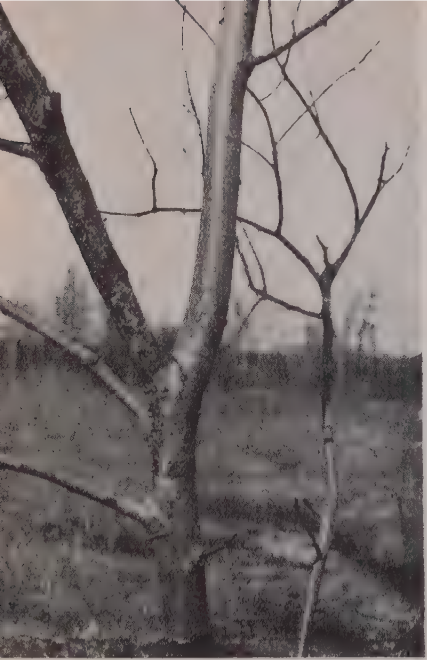
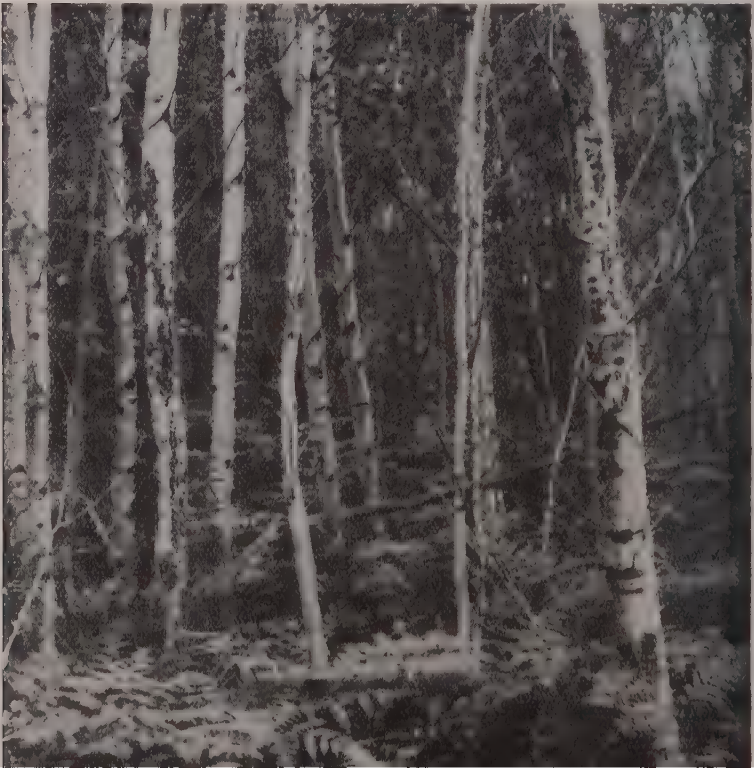


FIGURE 177. – Canker caused by *Hypoxylon pruinatum* on aspen (*P. tremuloides*). The fungus has invaded the main stem from a branch.

Courtesy *Canadian Department of Agriculture*

FIGURE 178. – Canker caused by *Hypoxylon pruinatum* in a stand of 22-year-old aspen (*P. tremuloides*), Petawawa, Ontario, Canada.

Courtesy *Canadian Department of Agriculture*



of the hybrids of Stout and Schreiner and on *P.* x *euramericana* cv. 'serotina'. *P. alba*, and *P. nigra* cv. 'italica' are both said to be resistant but the host range has not been fully worked out.

In 1941 the fungus was recorded in the Argentine, where *P. laurifolia*, and some Italian hybrids, including *P.* x *euramericana* cv. 'I-154,' are reported to be susceptible.

The fungus starts on twigs of the current year. These infected shoots are killed but the fungus travels down them to the main stem, where canker formation takes place. In the early stages the cankers caused by this fungus are sunken like those due to *Dothichiza* but later, as they get larger, they become scarcely distinguishable from those due to bacterial canker (weeping canker). *Cytospora chrysosperma* frequently occurs on the bark of trees killed by *Septoria*, or on the dead tissue in the cankers. The commonly occurring spore stage is the *Septoria* (imperfect) one. Small, not very conspicuous pustules, are found on the infected bark, from which, under moist conditions, the spores issue in long, curled, pinkish tendrils.

Since *Septoria* is, as far as is known, confined to the American continent, it is obvious that great care should be taken that it is not introduced into Europe or Asia, especially since the reaction to this fungus of the more important hybrids used there is not really known.

Hypoxylon canker

Hypoxylon pruinatum, Cke., an *Ascomycetous* fungus, is fortunately practically restricted to aspen and to the American continent, where, however, it is widespread. The fungus occurs on both *P. tremuloides* and *P. grandidentata*.

The fungus gains entrance through wounds but only occurs on the smooth-barked younger portions of the tree. Very large, strikingly black cankers are formed. On the trunks of 10-to-15-year-old trees the cankers may be 3 or more feet long before the stems are girdled and killed. According to Bier, the cankers occur very commonly on the healthy, fast-growing trees in a stand and are not in any way confined to suppressed trees or those weakened by other causes. On the other hand, Anderson associates the disease with poor sites, low stand density and the presence of other tree species within the stand.

It appears that in severely attacked stands losses can be quite serious. It is certainly a disease that should not be allowed to become more widespread.

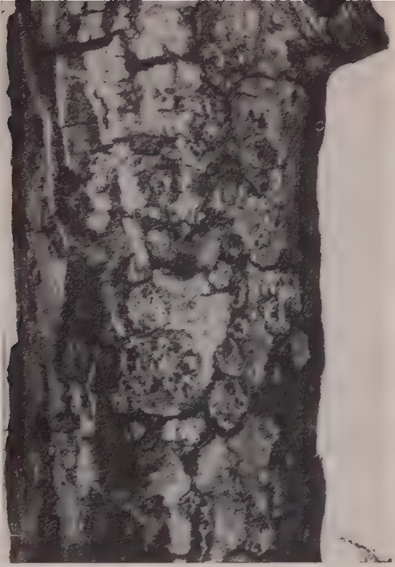


Figure 179. – A fruit body of *Hypoxylon pruinatum* on a 5-year-old canker.

Courtesy
Canadian Department of Agriculture

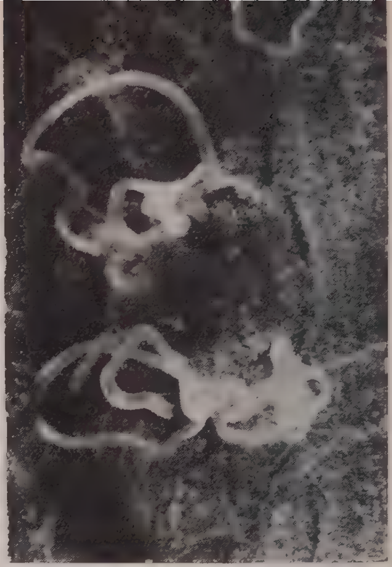


Figure 180. – Tendrils growing out of pycnidia of *Cytospora* on shoots of 4-year-old *P.* ' robusta ', at Sery-les-Mézières.

Courtesy *Laboratoire de l'Institut national agronomique de Paris*

Cytospora - Bark necrosis

Cytospora chrysosperma, (Pers.) Fr., the perfect stage of which is *Valsa sordida* Nitschke, occurs very commonly indeed as a saprophyte on dead poplar twigs and wood. The frequency with which it is found as a saprophyte has thrown considerable doubt on its occasional pathogenicity. Certainly, wherever it has been reported as a parasite, it has followed initial injury by some other cause. In Wisconsin, it has followed winter injury though it was suggested that the fungus did more damage than the initial frost. Schreiner considered that disease due to this fungus can be avoided by growing poplars under conditions conducive to fast, healthy growth. The heaviest infection is usually on young trees. He also mentions the occurrence of this fungus on stored cuttings and suggests storage at temperatures below 35° F. (2.7° C.) to avoid *Cytospora* injury of this kind. Drought has also been mentioned as a predisposing factor.

The typical symptoms associated with injury by this fungus are death of patches of bark, but true cankers are seldom formed, mainly because the attacked trees or stems are usually so weakened by the predisposing cause, that they cannot react with sufficient vigor to form any healing tissue. The commonly occurring *Cytospora* stage of the fungus fructifies in great quantity on the affected bark, the small erumpent pinhead-sized fruit bodies, somewhat similar to those of *Dothichiza*, producing under moist conditions vast quantities of spores, which issue forth as long, bright orange-pink tendrils.

The fungus is certainly but a weak parasite. Inoculations only succeed on plants or parts of plants previously weakened in some way. Certainly *Cytospora* is a much less dangerous fungus than *Dothichiza populea*, though their behavior is in many ways similar. It is quite definite that the provision of good growing conditions and the avoidance of unnecessary wounding is the best answer to both these fungi.

Müller-Stoll and Hartman give information on the susceptibility of various varieties but results differ from year to year. The almost universal occurrence of *Cytospora* on dead poplar bark of all varieties, and its undoubted association with conditions seriously weakening the tree, means that varietal resistance is unlikely to be clearly defined. It seems probable for any site that the poplars which will grow best are the ones most likely to avoid *Cytospora* attack.

Dothichiza bark necrosis and dieback

The fungus *Dothichiza populea* Sacc. and Briand is now regarded, in many parts of Europe, as the worst enemy of poplar growing. The perfect stage of the fungus is *Cenangium populneum* (Pers.) Rehm. It has also been described under the name *Chondroplea populea*.

The erumpent, pinhead fruit bodies of the fungus are produced on the dead bark killed by its action. Under suitable conditions cream-colored tendrils of spores emerge from them.

The voluminous literature on this fungus is almost unanimous on one point: the severity of attack is markedly increased by any circumstance which weakens the resistance of the poplar, such as drought or transplanting. Normally, infection is through wounds or through twigs which have died from other causes. But under suitable circumstances *Dothichiza* is most certainly an active parasite, capable of causing heavy losses in the nursery and in the field, particularly on unestablished or partly established plants.

Van Vloten reported that winter inoculations with this fungus led to more severe symptoms than summer ones. This work has recently been repeated by Schmidle, who has shown that inoculations in September, October, February and March (and therefore presumably in the intervening months of November, December and January), are much more successful than those carried out between April and August.

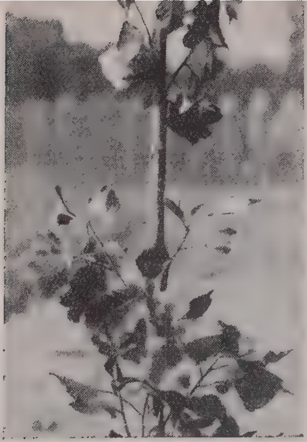


FIGURE 181. – Young poplars attacked by *Dothichiza populea* after being damaged in the nursery.

Courtesy *Zycha*

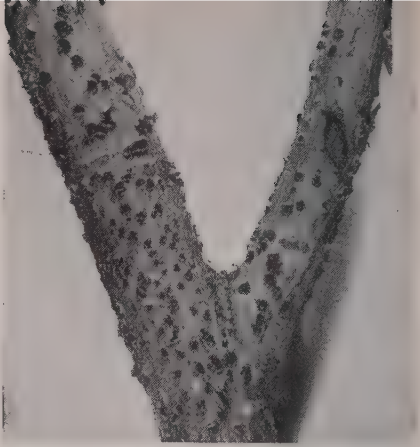


FIGURE 182. – Attack by *Dothichiza populea.*

Courtesy *Laboratoire de l'Institut national agronomique de Paris*

The disease appears to be very widespread. It has been suggested that it was introduced into the United States and Canada, but it is now common there. Recent reports have indicated its occurrence in Turkey, and it is very probable that it occurs in other parts of the Near East. A fungus closely resembling *Dothichiza* has been found in the Argentine.

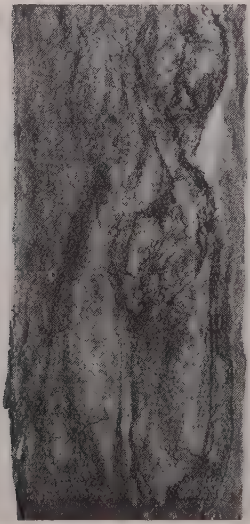


FIGURE 183. – Injury caused by *Dothichiza populea.*

Courtesy *Zycha*

In the early stages of attack the disease is merely a bark necrosis, the affected areas, spreading around the point of entry (a dead side twig, or a pruning scar), being slightly sunken. Often the affected stem is girdled at this stage and no canker formation occurs, but if the tree retains sufficient vigor, healing tissue will be formed and a simple form of canker arises. Attack by *Dothichiza* is not normally very persistent and most of the damage occurs in the winter, spring and early summer, following infection. Thus *Dothichiza* attack never results in the complex perennial canker, so typical of bacterial infection on poplars.

Information on varietal susceptibility is very incomplete. According to Van Vloten the balsam poplars are generally more susceptible than the black hybrids, many of which are resistant. *P.* x *euramericana* cv. ‘ regenerata ’, cv. ‘ gelrica ’, cv. ‘ eugenei ’ and cv. ‘ marilandica ’ are all resistant. Unfortunately, *P.* x *euramericana* cv. ‘ robusta ’ and *P. deltoides* ‘ missouriensis ’ (Dutch importation) and sometimes *P.* ‘ serotina ’ are susceptible. The *Dothichiza* susceptibility of *P.* x *euramericana* cv. ‘ robusta ’, justifies efforts being made to find other equally fast-growing and straight poplars to take its place. Further information on the resistance and susceptibility of the hybrid black poplars are given in the chapter on classification, identification and distribution.

Some, though not all, of the American hybrids of Stout and Schreiner are highly susceptible, but so far Italian selections have proved resistant. According to Bavendam, *P. alba* and *P. tremula* are resistant.

The question of varietal susceptibility and resistances is complicated by confusion between injury associated with this fungus and that associated with *Cytospora chrysosperma.* An additional difficulty lies in the frequency with which other fungi invade *Dothichiza* lesions, masking the original cause of the injury. However, control of *Dothichiza* depends less on choice of variety and more on cultural treatment. Avoidance of crowding in the nursery, careful transport and planting, and choice of suitable sites are the important factors in the control of this disease. Infected nursery stock should be uprooted and burned, for the attack is likely to develop further and to prove disastrous if infected plants are used in the field. Spraying nursery stock with Bordeaux mixture has been suggested, and this might well be tried in nurseries, especially on varieties known to be susceptible, as a matter of routine. Further experiments on the use of sprays are certainly desirable.

Stereum purpureum

The fungus *Stereum purpureum* Pers., cause of the well-known “ silver leaf ” of plums and other fruit trees, sometimes occurs on the branches of poplars, usually when they have been drastically cut back. It does little harm to the poplar but may act as a source of infection to nearby fruit trees. Unfortunately, of course, poplars planted primarily as shelter are often cut back, lest they shade the fruit trees. Such lopping should never be too drastic. If it is done fairly frequently and without the cutting of large branches, *Stereum* attack is unlikely to develop.

ROOTS

Armillaria mellea

Poplars are not particularly susceptible to root fungi, though *Armillaria mellea* (Vahl.), Quel. does occur occasionally, causing the death of roots and the weakening or even death of the whole tree. *Armillaria* attack is most likely to occur if poplars are planted on ground previously occupied by old hardwoods, the stumps of which serve as centers of infection. Affected trees should be felled and time allowed for the stump to decay thoroughly before any other poplars are planted near.

HEARTWOOD

Decay

Owing to the short rotation on which poplars are usually grown, decay is seldom a serious problem, for the destruction of the wood by fungi is normally a phenomenon of middle and old age in trees. When decay-causing fungi are reported on poplar it is nearly always on older trees.

For instance, *Fomes ignarius* (L.) Fr. has been reported in the United States and in other countries causing serious decay in aspen. But aspen poplars normally are grown on relatively long rotations, because of their slower growth, and the increment exceeds the loss from decay up to 70 years of age. *Trametes trogii* Berk. has been reported in the Argentine on *P. alba* and *P. tremula*, both species which are likely to be grown on a longer rotation. And finally *Fomes fomentarius* (L.) Kickx. (*Ungulina insengae* [De Nob.] Pal.) has been reported attacking poplars in France and Syria. But it is confined to trees older than the average plantation. In this case, the death as well as the decay of the trees is attributed to the action of the fungus. On old poplars, a considerable number of other decay-causing fungi may be found, none of which is likely to be of any importance in commercial cultivation, and there is no reason therefore to name them individually.

Pholiota destruens (Brond.) Fr. seriously attacks the heartwood of poplars after felling.

Black heart and wetwood

It is well known that the heartwood of poplar is very often found after felling to be stained to a greater or lesser degree. This staining is seldom of fungal origin, that is, it is not an early stage of decay, and normally

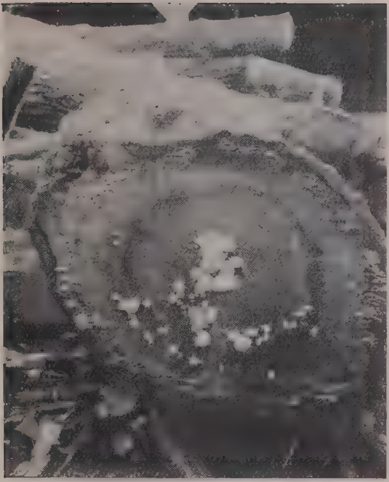


FIGURE 184. – End of a poplar log, showing fructifications of *Pholiota destruens* and of *Stereum purpureum* on the periphery.

Courtesy *Ph. Guinier*

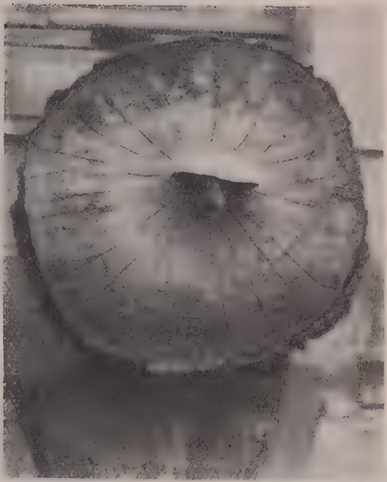


FIGURE 185. – End of a poplar log, showing fructification of *Pholiota destruens*.

Courtesy *Ph. Guinier*

FIGURE 186. – *Polyporus fomentarius* on old poplars at Troyes, France.

Courtesy *R. Rol*

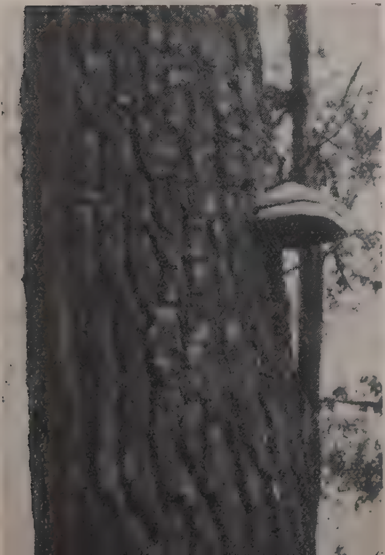
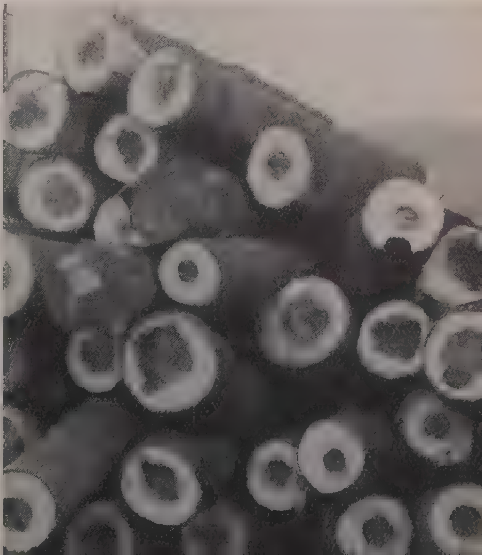


FIGURE 187. – "Black heart" on logs of probably *P.* x *euramericana* 'robusta' at Grammont, Belgium.

Courtesy *Forestry Commission*



it has little effect on the strength of the wood. Varied opinions are expressed on the importance of this stain in the utilization of the timber. Some say that the stain soon fades and is therefore of no consequence, while others consider that it greatly lowers the value of affected trees. Of course, in veneer logs a good deal of the stain will in any case be in the core.

It is probable that differences of opinion on the question of fading are due to the fact that different types of staining are being considered. Paler watery stains normally do fade as the wood dries, but there is certainly a darker type of stain, which remains dark enough to have a real effect in utilization.

Very little is known about the causes of this drawback. Magyar has put forward fungal infection as the cause of red heartwood in poplar in Hungary. In the United States, bacterial infection has been found in the case of " wetwood, " an abnormal accumulation of water in the heartwood. But in this instance, although watery staining of the wood is involved, the primary importance of the disease lies in the fact that, in heavily infected poplars, dieback or even death results. In Belgium " dark heart, " which is considered quite serious by the match industry, has been attributed to bacterial infection.

Obviously the whole question of stain is largely unexplored. Until the different kinds of stain have been distinguished, their frequency of occurrence found, and their causes elucidated, it is hardly possible to give any reasoned view on their real importance in poplar cultivation.

C. Virus diseases

A possible virus disease of poplars has been reported from Yugoslavia. Chlorosis of the foliage is followed by premature leaf fall. Variegation, which might well be of virus origin, is known to occur occasionally in poplars. It can certainly be stated that at the moment no really serious virus disease of poplars is known.

D. Diseases due to higher plants

Mistletoe

The common mistletoe, *Viscum album* L., is very widespread on poplars in northern France. It also occurs on poplar in other European countries but not in such concentration. It is completely absent from Italy.

The degree of attack varies on different varieties. *P.* x *euramericana* cv. ' robusta ' is certainly relatively resistant, and is always less attacked than, for instance, *P.* x *euramericana* cv. ' regenerata '. Heavily infested trees in France tend to show some yellowing of the foliage but there appears to be little diminution of the growth rate, and the mistletoe itself has some commercial value.

Lathraea clandestina

Lathraea clandestina L., a curious parasitic plant with purple flowers, somewhat reminiscent of crocuses, has poplar and willow as its hosts. It occurs in various European countries including Spain, France and Italy. It does no damage to the trees.

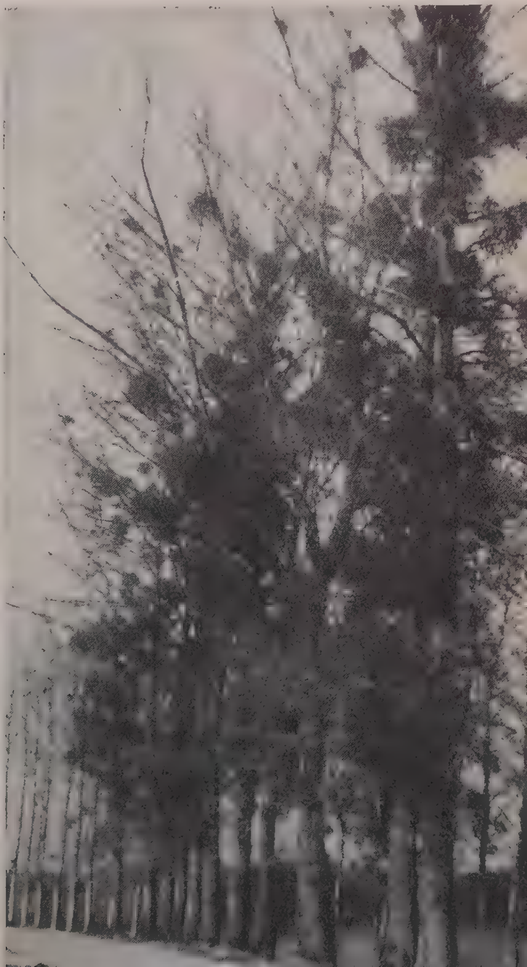


FIGURE 188. – Poplars loaded with mistletoe at Saint-Quentin-le-Verger, France.

Courtesy *J. Pourtet*

TABLE 12. – DISTRIBUTION OF PRINCIPAL POPLAR DISEASES

Disease	Europe	Near East	Far East	North America	South America
Venturia Spring defoliation	common, serious in Italy	not recorded	not recorded	present but not serious	not recorded
Phyllosticta Dieback	present, sometimes serious in Italy	not recorded	not recorded	not recorded	not recorded
Pestalozzia Shoot disease	not recorded	not recorded	present in Japan, not serious	not recorded	not recorded
Marssonina Leaf spot	common but not serious	present in Iran	not recorded	common and severe in places	not recorded
Septotinia Leaf blotch	present in the Netherlands but not serious	not recorded	not recorded	present and severe in places	not recorded
Septoria Leaf spot	present (*S. populi*) but not serious	present in Iran (*S. populi*) but not serious	not recorded	present (*S. musiva* and *S. populicola*), not serious on leaves	present (*S. musiva* and *S. populi*), not serious on leaves
Taphrina Leaf blister	present but not serious	doubtful	doubtful	present but not serious	doubtful
Melampsora Rust	common but seldom serious	various European species	present in Japan (*M. magnusiana*)	common but different species from Europe	present; at least one European and one American species

TABLE 12. – DISTRIBUTION OF PRINCIPAL POPLAR DISEASES *(concluded)*

Disease	Europe	Near East	East Asia	North America	South America
Pseudomonas syringae Weeping canker	common in Europe and serious on some varieties	not recorded	not recorded	not recorded	not recorded
Other bacterial diseases	" brown spot " in southern Europe is moderately serious	tumor-like cankers occur	not recorded	not recorded	not recorded
Nectria Canker	present	doubtful	doubtful	doubtful	doubtful
Septoria Canker	not recorded	not recorded	not recorded	present and serious on some hybrids	present
Hypoxylon Canker	not recorded	not recorded	not recorded	present and in places serious	not recorded
Cytospora Bark necrosis	common, usually secondary	doubtful	doubtful	common, usually secondary	doubtful
Dothichiza Bark necrosis	common and serious	present in Turkey	doubtful	common, sometimes serious	probable
Armillaira mellea Root disease	present, not serious	doubtful	doubtful	present, not serious	doubtful

E. DISTRIBUTION OF THE PRINCIPAL DISEASES

In Table 12 the principal diseases of poplars are set out in a form which is intended to show their distribution in the principal poplar-growing regions. It must be admitted that the large number of records under Europe and North America and the small number under eastern Asia reflect to some extent the intensity of pathological research in those regions.

Perhaps the main importance of this table is that it illustrates clearly how many of the poplar diseases have only a regional distribution. The importance of this fact is discussed further in the section on the control of poplar diseases.

F. SYMPTOMS OF THE PRINCIPAL DISEASES

Table 13 is not intended to serve as a key to the determination of the various diseases of poplar but it might well facilitate their identification.

G. CONTROL OF POPLAR DISEASES

Two points are of paramount importance in the consideration of poplar disease control. The first is the fact that many of the most important poplar diseases have still only a limited distribution; the second is that poplars show strong varietal resistance and susceptibility to many of the diseases attacking them.

The principal means of control are considered in the light of these two factors.

Spraying

Very little work has been done on the use of fungicidal sprays against poplar diseases. As with other forest crops, the value of the trees per annum can hardly support the high cost of plantation spraying, though no doubt such means could be used in the control of foliage diseases, such as that due to *Venturia*. Only in the nursery can spraying be used economically, and there it is feasible against many of the leaf diseases, though it would probably be less effective against *Melampsora* rust than against most of the others. It may well be that regular fungicidal spraying would be justified in a poplar nursery. Unfortunately, very little work has been done on the use of modern sprays and no detailed spraying recommendations can be made.

TABLE 13. – SYMPTOMS OF THE PRINCIPAL POPLAR DISEASES*

Name of disease	Part of tree attacked	General appearance of damage	Fungal or bacterial symptoms
Spring defoliation (*Venturia* spp.)	leaves and succulent shoots	withering and blackening	inconspicuous
Dieback (*Phyllosticta populina*)	leaves and succulent shoots	withering and blackening	inconspicuous
Shoot disease (*Pestalozzia populi-nigrae*)	young shoots and smaller twigs	brown lesions and dieback, later cankers	dark pinhead fruit bodies
Leaf spot (*Marssonina* spp.)	leaves	black spots and later withering	tendrils of white spores
Leaf blotch (*Septotinia populiperda*)	leaves	brown spots, followed by withering	white masses of spores on both leaf surfaces
Leaf spot (*Septoria* spp.)	leaves	brown spots, followed by withering	small black pinhead fruit bodies
Leaf blister (*Taphrina aurea*)	leaves	blister-like distortion, followed by some leaf fall	conspicuous yellow patches on the underside of the leaf
Rust (*Melampsora* spp.)	leaves, very occasionally young shoots	withering and leaf fall	conspicuous yellow pinhead fruit bodies on the underside and to a lesser extent on the upper surface of the leaves
Weeping canker (*Pseudomonas syringae* fm. *populae*)	twigs, branches and trunk	dieback and highly erumpent cankers	exudation of grayish bacterial slime from cracks on young twigs in the spring

TABLE 13. - SYMPTOMS OF THE PRINCIPAL POPLAR DISEASES* (*concluded*)

Name of disease	Part of tree attacked	General appearance of damage	Fungal or bacterial symptoms
Brown spot (Bacteria)	bark	discoloration and death of small patches of bark and cambium, leaving black inclusions in the wood	none
Canker *Nectria coccinea*	twigs, branches and trunk	dieback and open cankers	red pinhead fruit bodies in the cankers
Canker *Septoria musiva*	twigs and branches	dieback and canker	small black pinhead fruit bodies
Canker (*Hypoxylon pruinatum*)	branches and trunk	black cankers	ruptures in bark exposing gray layer of spores
Bark necrosis (*Cytospora chrysosperma*)	twigs and stem, mainly on young trees	Death of patches of bark, and dieback of stems	pinhead fruit exuding tendrils of orange spores
Bark necrosis (*Dothichiza populea*)	twigs and stem, mainly on young trees	Death of patches of bark, upper part of tree	black pnhead fruit bodies
Stereum purpureum	mainly on dead stubs	restricted decay	small, purple, bracketlike fruit bodies
Bootlace fungus (*Armillaria mellea*	roots	death of roots, and sometimes of whole tree	clumps of orange - brown toadstools at base of tree
Decay (*Pholiota destruens*)	felled trees	decay	clumps of large whitish toadstools on section

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* Decay-producing fungi, which occur only occasionally on poplars, are not included in this table.

It is certainly sound practice to remove trees affected by the more serious perennial diseases, such as *Dothichiza* bark necrosis or bacterial canker. It is particularly important that this should be done in the case of trees infected with stem fungi in the nursery, for infected trees planted in the field will often die. This is particularly the case with *Dothichiza*, so that trees known to be infected with this fungus should never be used for planting.

Quarantine

It is obvious that precautions should be taken to prevent the spread of poplar diseases from one country to another, and particularly from continent to continent. The sending of poplar plants from one country to another should certainly be restricted to adjacent countries, and under no circumstances should plants be sent from one continent to another. Even in the transmission of cuttings there is an element of risk. Cuttings should be restricted to a number just sufficient to start a new stock. They should be surface-sterilized before dispatch and possibly again on receipt. Half a centimeter should be cut from each end on receipt and burned in case fungal spores have been sucked into the vessels, and the cuttings should be planted under conditions of semi-isolation, in a place where they can be kept under frequent observation, lest disease appear on them.

At the Sixth Session of the International Poplar Commission in 1952 a number of recommendations were made regarding the exchange of plants and cuttings; a distinction was made between the exchange of cuttings between countries within the same continent and exchanges from one continent to another, which are dealt with in Appendix 1.

The satisfactory sterilization of cuttings is not an easy matter. Many fungicides, if applied at a sufficient strength to kill fungal spores, will damage the rooting ability of the cuttings. However, a satisfactory method has been elaborated in the United States, involving the use of "Semesan." It has been shown that this substance is an effective sterilizing agent for poplar cuttings from the standpoint of protection from *Septoria musiva*, *Dothichiza populea*, and *Septotinia populiperda*. The material used at the recommended strength does not damage the cuttings or impair their ability to root.

The cuttings should be completely immersed in a 1 percent suspension of " Semesan " (30 percent hydroxymercurichlorophenol) for a period of 20 minutes; no rinsing is necessary before packing for shipment. It is to be hoped that this practice will be adopted whenever cuttings are sent from one country to another.

Varietal resistance

At the moment, however, varietal resistance is certainly the most hopeful method of combating poplar diseases. It has been stressed above, under the various disease headings, that most of the serious diseases are subject to this principle. Thus, any one disease can usually be avoided by the use of resistant varieties or clones. The number of serious diseases present in any one country is usually sufficiently small for this to be done. If, as is usually the case, only two or three diseases are serious in any particular country, they can usually be avoided by choice of poplar variety, without unduly limiting the number of varieties available for use. If, however, the dangerous diseases, which at present have a limited distribution, such as bacterial canker or *Septoria* canker were to become widespread, varietal selection against so many diseases would become a well-nigh impossible task. The possibility of using this, the most valuable means of poplar disease control, depends therefore on the success of quarantine measures in restricting the spread of those diseases which still have limited distribution.

APPENDIX 1

THE TRANSMISSION OF POPLAR DISEASES FROM ONE COUNTRY TO ANOTHER

Report of the Working Group set up at the Fifth Session of the International Poplar Commission, 1951

by

Messrs. R. ROL (France), H. VAN VLOTEN (Netherlands)
and T. R. PEACE (Great Britain)

The dangers inherent in the transmission of poplar, and particularly poplar cuttings, from one country to another, and especially from one continent to another, have been stressed by Dr. G. F. Gravatt of the United States Division of Forest Pathology, in his paper on " The Danger of Spreading Diseases on Poplar Cuttings, " which was presented at the Fifth International Poplar Congress in 1951. It is only necessary here to mention a few special points. Firstly, there are several serious diseases of poplar, in particular the cankers caused by *Septoria musiva* and by *Pseudomonas syringae* f. sp. *populea*, which have only a limited distribution and could presumably do damage over a much wider area if spread on cuttings or other material. Secondly, fungi such as the poplar rusts (*Melampsora* spp.) are known to vary from continent to continent, so that the transmission of these fungi from one continent to another might result in clones previously resistant being attacked by the newly introduced species or strain of the fungus. It may well be found that fungi of almost universal distribution, such as *Dothichiza populea*, have strains in different countries, so that its introduction from abroad, even into countries already infected, might result in increased damage. Finally, the propagation of poplar on a clonal basis means that if a disease or pest is introduced, to which one particular clone is susceptible, all the trees of that clone will react to the disease or pest in a like manner, and losses are bound to be severe. All these reasons make it highly desirable that great care should be taken, lest by allowing the easy transmission of poplar cuttings from one place to another, we eventually produce a universal distribution of all poplar pathogens.

At the moment it would obviously be easier to restrict the transit of cuttings from one continent to another, than from country to country in the same continent. For this reason separate proposals are submitted for these two cases. It should be made clear that in the suggestions made below, " Poplar " is intended to apply to all members of the genus *Populus*.

1. *Transmission of cuttings and plants from one country to another in the same continent*

In practice, so far as the International Poplar Commission is concerned, this means between countries in western and northwestern Europe. It would probably be reasonable to regard Austria, Belgium, Denmark, France, Great Britain, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and Western Germany as a continental unit for this purpose. There are obviously strict limitations on the sanitary measures that can be taken without hampering legitimate trade in cuttings and plants. Any extension of the regulations already in force for some countries with regard to certified stocks of poplar is likely to have a good effect, since these stocks will normally be of varieties resistant to bacterial canker and are likely to be well looked after in the nurseries, and therefore kept free of diseases and pests. There is no doubt that certification of poplar stocks is one of the most valuable aids in the exchange of disease-free poplar material.

In Great Britain licences are required to import poplars. In practice these are normally granted for small or large quantities of poplar known to be suitable for timber production and resistant to bacterial canker, provided they are certified true to name by a government agency in the exporting country. They are also normally granted for small quantities of ornamental varieties. The licences have two distinct values as regards sanitation. Firstly, they provide an automatic record of all imports and their destination, and secondly, they can be used to control imports and thus enforce some of the regulations for intercontinental traffic suggested in Section II.

It is suggested that the attention of the nursery trade should be called to the importance of sanitation in regard to poplars. Exporting nurseries should be asked to see that all plants and cuttings sent to other countries are healthy, and that all diseased poplars are removed from the nursery and its neighborhood. Importing nurseries should be asked to keep plants or cuttings received from other countries under observation for one to two years and to destroy any that show evidence of serious disease. If any disease or pest not generally distributed in Europe (*Dothichiza populea* is an example of a generally distributed disease), is known to exist in the neighborhood of an exporting nursery, the exporter should be asked to warn the person receiving the plants, so that a special lookout can be kept for the disease in question on the imported plants. If possible these precautions should be supported, and to some extent enforced, by the Plant Pathological Service of the country concerned. This would be one means of bringing them to the notice of the nursery trade; another useful method would be through the medium of the trade papers; all possible means should be used.

2. *Transmission of cuttings and plants from one continent to another*

Here it should be possible to introduce much more stringent regulations without serious damage to trade, and the much greater risk involved, particularly as regards the possibility of bacterial canker reaching America or *Septoria* canker reaching Europe, would certainly justify their introduction. The following recommendations should, if possible, be made a part of the quarantine legislation of member countries, but, where this is not possible, persons concerned should be asked very strongly to adopt them on a voluntary basis.

- *i*) Exchange of material should take place through a strictly limited number of channels, preferably through institutions, persons or firms nominated by the National Poplar Commissions.
- *ii*) Exchange of material should be limited to cuttings, grafting material, seed and pollen.

iii) The number of cuttings of any one clone exported in one year to one recipient should be limited to fifteen.

iv) Each National Commission should keep a central record of all exports and imports, naming the clone concerned, the place of origin and the name of the person and institution receiving the cuttings.

v) The nursery where the cuttings or other material are produced, or the trees from which they are collected, and any place where they are stored, should be at least one kilometer from any poplar suffering from bacterial canker or from *Septoria musiva.*

vi) The plants in the nursery where the cuttings are produced, should be sprayed or dusted at least twice with a general-purpose fungicide, and at least twice with a general-purpose insecticide, during each season.

vii) All cuttings and grafting material should be surface-sterilized before dispatch with materials capable of destroying fungi and insects. (It is hoped to be able to make definite recommendations on this matter in the near future as a result of work being carried out in the United States by Dr. A. Waterman.) The ends of the cuttings should be wax-covered to prevent the sucking of air and spores into the vessels.

viii) On receipt all cuttings should have 1 centimeter cut off from each end and burnt, and should then be re-sterilized.

ix) All cuttings received from another continent should be grown for at least two years in a nursery, not less than 0.75 kilometer from any home-grown poplar trees or normal poplar nurseries.

x) Any person receiving cuttings from another continent should not pass on any material to another country in his own continent, until the plants, resulting from the cuttings, have been grown for at least two years, i.e., until they can be declared reasonably free of imported diseases and pests.

It is suggested that these recommendations might be submitted to certain nonmember countries likely to be concerned, in particular to the United States, Canada and the Argentine Republic.

GENETICS AND BREEDING OF POPLARS

It has been clearly shown that the Linnean species is not at all uniform from the hereditary point of view. On the contrary, it is often very multiform, split up into geographical strains and local forms, and even varying to the extent that every individual has a peculiar genotype of its own. As far as plant life in general is concerned, genetic knowledge has been mainly derived from studies of herbaceous plants. *A priori*, it is very probable that the laws of heredity generally applicable to very different groups of herbaceous plants, as well as to the animal kingdom, also apply to woody plants, of which a number of subspecies and varieties have been identified and named. Many of these represent definite deviations from the normal type, such as weeping and columnar forms. It has long been known that such deviations are hereditary, at least in the sense that they maintain themselves by vegetative means, which proves that they are not mere modifications caused by exceptional environmental conditions. With sexual reproduction, however, it has been found that often only a small portion of the progeny exhibits the characteristics of the mother tree. The genus *Populus*, whose dioeciousness accounts for its large number of hybrids, is almost invariably propagated vegetatively, and hence offers excellent opportunities to geneticists.

Attention was first drawn to the possibility of raising improved poplar strains experimentally by A. Henry in England in 1910. Henry's starting point was the fact that several cultivated. fast-growing poplar strains were considered by taxonomists to be hybrids. The history of a few of these cultivated types was known. Thus, the cultivated poplar known as *Populus* 'eugenei' originated before 1832 in the nursery of Simon Louis Frères at Plantières near Metz in France. In the same nursery the form *Populus* 'robusta' had also originated around 1900 through the natural hybridization of two species. As valuable poplars had undoubtedly originated by random hybridization in nature, planned experiments with carefully selected parent species should, according to Henry, give still better results. He therefore carried out such experiments, and in

1914 produced the hybrid between *P. angulata* and *P. trichocarpa* known as *P.* x *generosa.*

From 1916 onward in the United States, and later in many other countries, as research into forest tree breeding progressed, poplars came more to the fore. At a later period, special poplar institutes were created, notably in Italy and Belgium. Thus, in a certain sense, the poplar may be called "the guinea pig of forest tree breeding" (Pauley, 1949).

I. GENETIC AND BIOLOGICAL FACTS OF IMPORTANCE FOR POPLAR BREEDING

Differentiation and variation

In the breeding of a plant genus, its differentiation and variability are of fundamental importance. For information on the classification of the genus *Populus* into species, its grouping into sections, and for its geographical distribution, reference should be made to the chapter on classification, identification and distribution of poplar types.

Here it is sufficient to recall that the species of poplar have been grouped in five sections, three of which are of prime importance: *Aigeiros* (black poplars); *Tacamahaca* (balsam poplars); and *Leuce* (aspens and white poplars). Within each of these sections, some ten reasonably well-defined species are recognized. The black poplars are most differentiated in North America; in Europe they are only represented by one species, *P. nigra*, and in east Asia by none. This section has a more southern distribution than the other two, with its southernmost boundary at about 30° N. and its northern boundary at 55° N. Ecologically, the black poplars are adapted to the alluvial soil in valley bottoms. Balsam poplars, which are confined to North America and east Asia, are widely distributed from south to north and some of them (*P. trichocarpa* and *P. tacamahaca* in America, and *P. suaveolens* in Asia) extend northward to the 70th parallel.

The two aspen species of the section *Leuce*, *P. tremuloides* in North America and *P. tremula* in Eurasia, occupy a broad, coherent, circumpolar region with the arctic tundra as its northern boundary. The aspens are less bound to alluvial soils than are other poplar species, and attain very good development on immense areas of moraine soil. The true white poplars, which have a much less northern distribution than the aspens, extend in the south as far as the 30th parallel.

The intraspecific morphological variation is considerable in several species, particularly in the American black poplars and in the aspens. From a genetic point of view, it is plausible to consider all American black

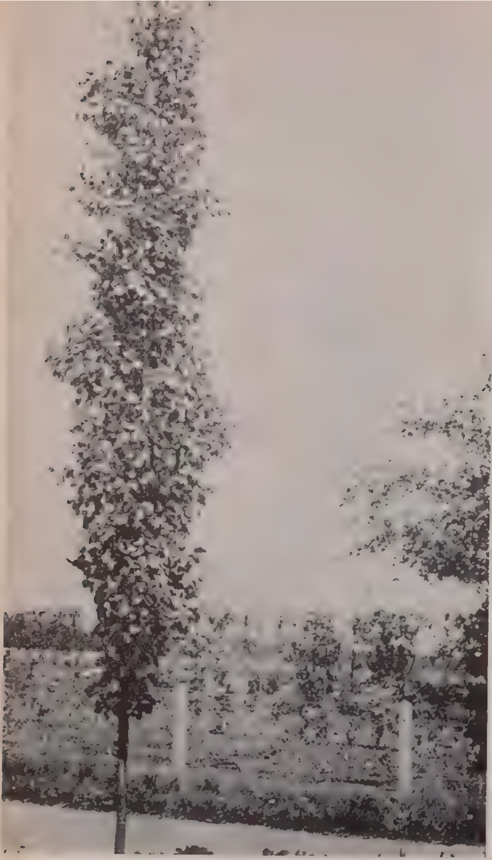
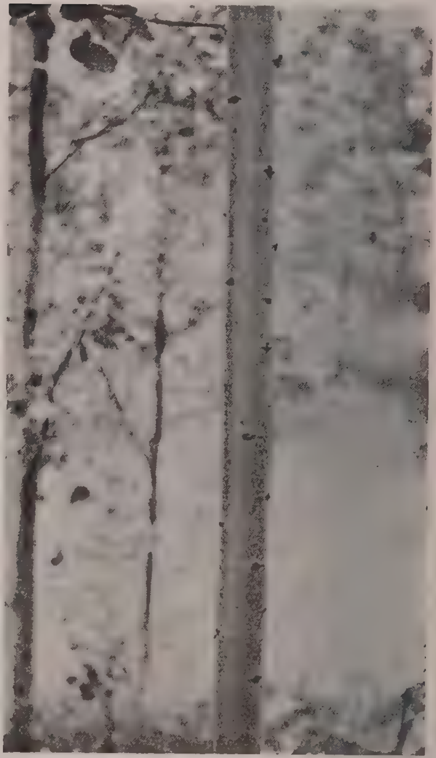


FIGURE 189. – *P. tremula* var. *erecta*,

Courtesy *H. Johnsson*

FIGURE 190. – *P. tremula* x *tremuloides*, F_1, typical smooth bark.

Courtesy *H. Johnsson*



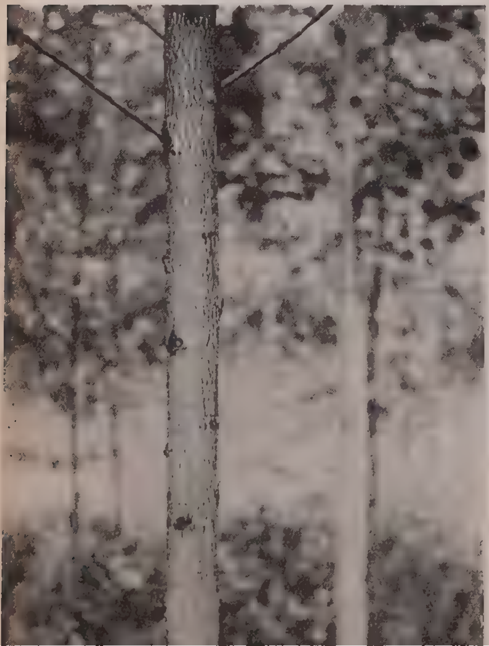


FIGURE 191. – *P. tremula* x *tremuloides*, F_1, deviating, fissured bark.

Courtesy *H. Johnsson*

poplars as belonging to the collective species *P. deltoides*, but taxonomists have recognized several species and subspecies, often with diffuse boundaries. It is by no means surprising that a species with a large geographical distribution such as *P. deltoides*, in a region with very varied climatic and edaphic conditions, should develop isolated populations, which differ one from the other. Subspecies have also been described in the aspens: in *P. tremuloides* the subspecies *P. aurea*, occurring in the Rocky Mountains and the Pacific Coast forms *P. vancouveriana*; in *P. tremula*, one subspecies, *P. villosa*, is mentioned, and an east Asiatic subspecies, *P. davidiana*, has also been recognized.

Drastically deviating forms are also encountered. The columnar form of *P. nigra*, given the name of *P.* ' italica ', is well known. A similar form of *P. tremula* was found as a single tree in Sweden some 50 years ago. It has been described as *P. tremula erecta* Sylvén and has been propagated vegetatively, so that it is now widely distributed as an ornamental tree. Undoubtedly, a wide morphological variation occurs within species of poplar, particularly within species with a wide geographical distribution.

Very little is known about the transmission of morphological characters from generation to generation in poplars. Thus the columnar form appears to be dominant in certain crosses and recessive in others.

Two other characters of considerable practical importance — very branchy growth, or the absence of side branches — were studied by Heimburger in Canada in 1940, in the crossing of two hybrids between the *Aigeiros* and *Tacamahaca* sections: Northwest poplar (probably *P. deltoides* x *P. tacamahaca*) and *P.* x *berolinensis*, in which a high degree of branchiness appears to be dominant and due to a single gene: number of plants of good form,[1] 26; very branchy plants, 14; plants without lateral branches, 12.

In a cross between *P. tremula* from south Sweden and *P. tremuloides* from Ontario, segregation into two bark types has been noticed. One is typical, with smooth, light grayish bark (Figure 190); the other has a fissured brown bark (Figure 191). Of 1,059 6-year-old trees, 930 were normal and 129 fissured-brown. This ratio approximates to 7 typical to 1 fissured-brown, and may be explained in several ways. It may be that two complementary, recessive factors are involved, located in the same chromosome and giving 25 percent crossing over. If so, one of the parents must be heterozygous for both these genes, and the other one double recessive. Only continued experiments can supply the answer to this question.

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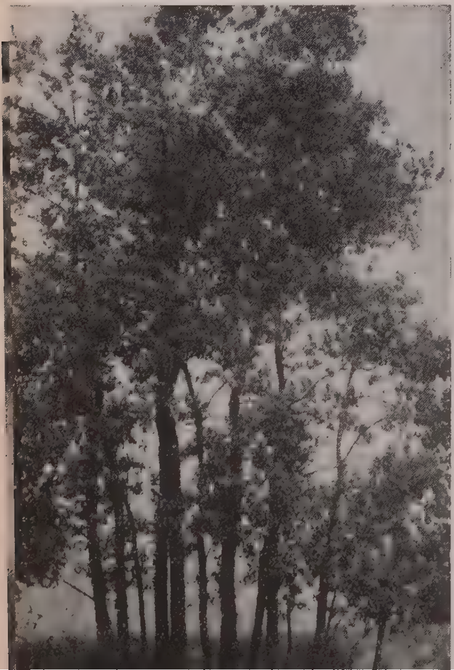
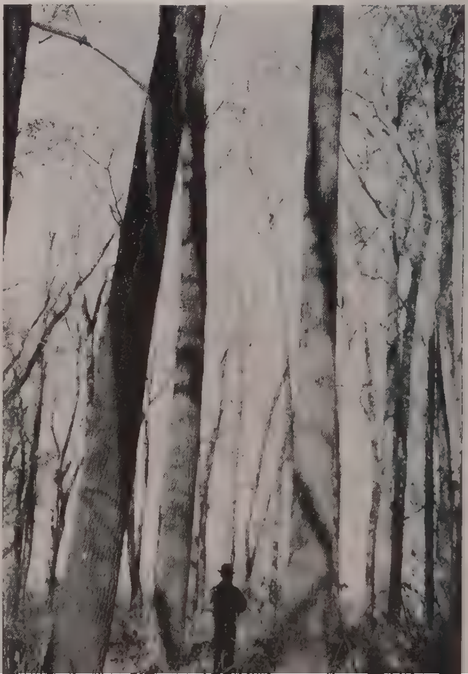
[1] Bushy seedlings were discarded.

In different poplar species, of course, there also exists a wide variation in quantitative and qualitative properties, such as the shape of the trunk, self-pruning and growth of height and diameter, all of which have a direct influence on the technological value of the tree. Extreme types of habit in *P. deltoides* are shown in Figures 192 and 193. Figure 192 shows a North American black poplar growing wild on an exposed site, located on Long Point Peninsula in Lake Ontario. This locality is situated rather near the northern limit of the species. Figure 193 illustrates a black poplar of quite another, and much more valuable type, growing by the Dutzo River in Missouri. In this case the dissimilarity of habit is also accompanied by morphological differences. Most probably the taxonomist would label the Ontario tree *P. monilifera* and the Missouri tree *P. missouriensis*. Figures 194 and 195 demonstrate a parallel case in *P. tremuloides*. Figure 194 shows a mature stand of this aspen on the prairie in Alberta and Figure 195 shows aspens in North Alberta along Lesser Slave Lake. Figures 196 and 197 give a similar comparison for

FIGURE 192. – *P. deltoides* on an exposed northern site at Long Point, Ontario, Canada, at latitude 42° 30′ N.
Courtesy *H. Johnsson*

FIGURE 193. – *P. deltoides*, Dutzo River, Missouri, U.S.A., at latitude 38° 50′ N.
Courtesy *H. Johnsson*





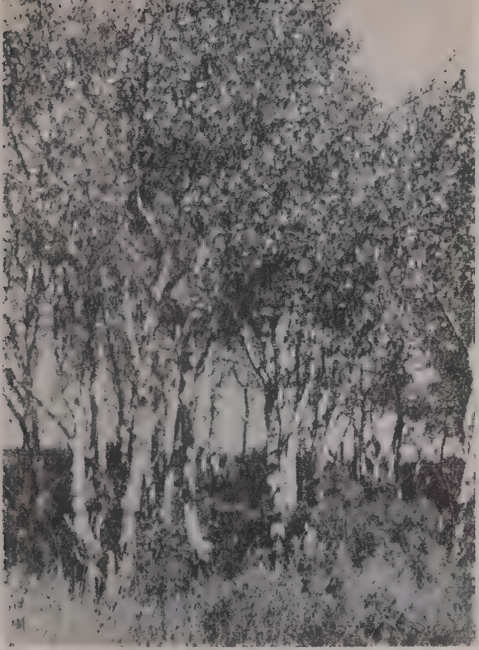


FIGURE 194. – *P. tremuloides* on the prairie in Alberta, Canada.

Courtesy *H. Johnsson*

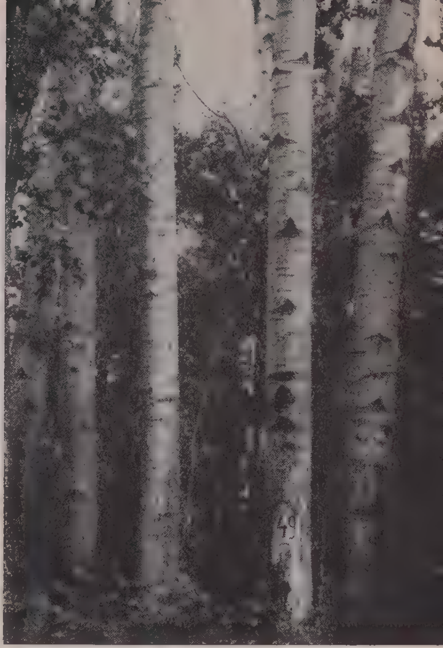


FIGURE 195. – *P. tremuloides* at Lesser Slave Lake, Alberta, Canada.

Courtesy *H. Johnsson*

P. tremula. Figure 197 shows a site in southern Sweden and Figure 196 a more northern site.

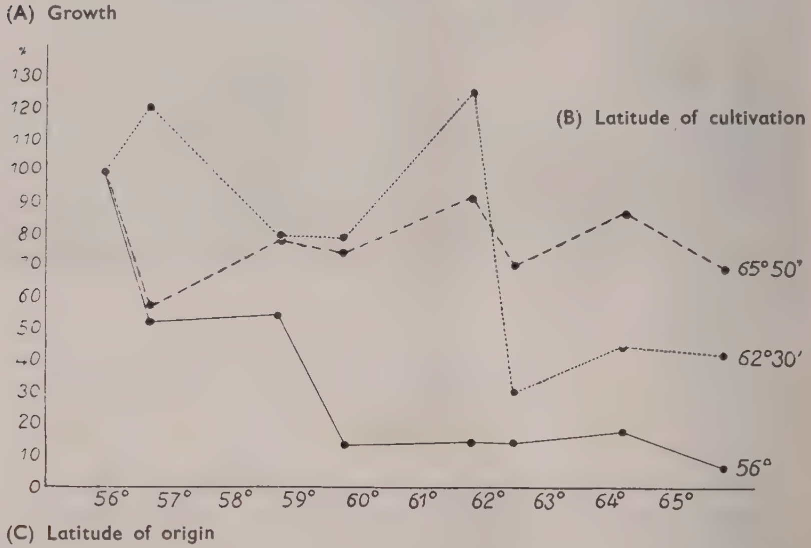
It is well known that a difference in phenotype need not be caused by a difference in genotype. Such questions can only be solved experimentally. However, one can safely postulate that, for instance, the aspen in Figure 194 represents a praire ecotype, genetically dissimilar to the nordic forest ecotype in Figure 195.

The morphological variation is, of course, to a certain degree an expression of an underlying physiological variation. However, a physiological variation which does not manifest itself immediately in morphological differences must also be taken into account.

Photoperiodicity

Varying photoperiodical adaptation represents a physiological variability of decisive importance. Long- and short-day types, with regard to vegetative growth, occur particularly in *P. tremula*. The tree populations of the north of Sweden are genetically adapted to long summer days and do not normally develop in climates with short photoperiods. When cultivated in southern localities their growth is reduced (Figure 198).[2] This phenomenon is illustrated by Diagram 10, which is based

DIAGRAM 10. – GRAPH SHOWING THE RELATIONSHIP BETWEEN HEIGHT GROWTH DURING THE FIRST YEAR FOR FAMILIES OF *P. tremula* OF VARYING GEOGRAPHIC ORIGIN AND THE LATITUDES OF THE REGIONS WHERE THEY ARE CULTIVATED. THE HEIGHT OF THE TREE IS EXPRESSED AS A PERCENTAGE OF THE FAMILY HAVING THE MOST SOUTHERN LOCATION



on figures for the height growth of *P. tremula* during the first summer, published by Sylvén (1940). In this experiment eight families originating between latitudes 55° 54′ N. and 65° 50′ N. are cultivated on three sites, situated on latitudes 56° N., 62° 30′ N. and 65° 50′ N. On the southern site, only the most southern progeny grows normally; on the next site the five most southern progenies develop normally but the three northern ones are underdeveloped. On the most northern site all progenies show normal growth.

In Diagram 11 the same phenomenon is shown, observed in a seven-year-old experiment on latitude 56° N., carried out with six families from different latitudes. The columns represent the mean heights of the fami-

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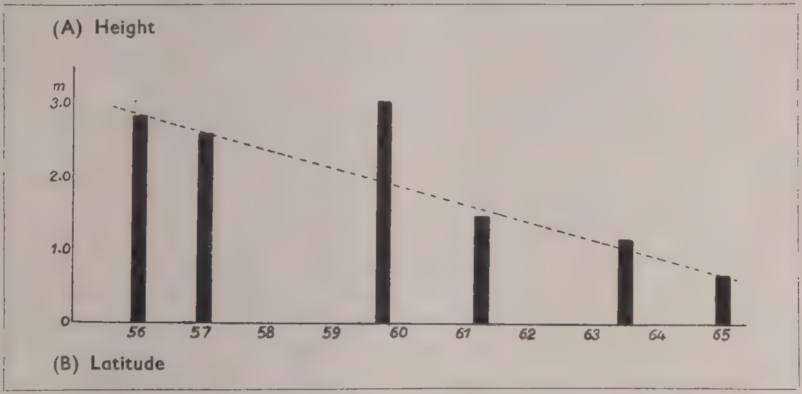
[2] Normal growth can be restored by artificial lighting, thus extending the period of daylight.

Diagram 11. – Diagram showing the mean height of several 7-year-old families of *P. tremula* of varying geographic origin, cultivated at latitude 56° N.



lies at an age of seven years, calculated on three replications with 100 trees per plot. Ignoring for the moment the family from 60°, the others form a series, continously decreasing from south to north. The mean height for the most southern family is 2.86 meters but for the most northern only 2.69 meters. The family from 60°, which breaks the series, proves that exceptional individuals of a more neutral type occur. In other words, the individual variation may outweigh the variation due to latitude. This experiment also includes dial crosses between 56°, 60° and 63° 30′. The height growth for these "provenance crosses" is compared with the growth of the pure provenances in Table 14.

Table 14. - Mean tree height in meters at an age of 7 years for aspen families with parents from different latitudes

♀ \ ♂	56°	60°	63° 30′	Mean females
56°	2.86	3.30	2.69	2.95
60°	2.95	3.07	2.37	2.78
63° 30′	1.93	2.84	1.20	1.99
Mean males	2.91	3.07	2.09	—

As is seen, the hybrids hold fairly intermediate positions between the latitude progenies. The averages for the females form the series 2.95, 2.78, 1.99 from south to north. For the males this series is 2.91, 3.07, 2.09. Apparently the male tree from 60° has an exceptional constitution and must thus be considered to be the main cause of the exceptional progeny illustrated in Diagram 11.

This hereditary differentiation is certainly not confined to *P. tremula*, but has also made its appearance recently in the United States in *P. tacamahaca*, *trichocarpa* and *deltoides*. Thus, Pauley and Perry have obtained the following results:

a) for clones of *P. tacamahaca* originating from latitude 42° to 60° N., a correlation coefficient r = –0.893 between the date when upward growth ceased near Boston and the latitude of origin;

b) for clones of *P. trichocarpa* whose origins were located between latitudes 33° and 61° 1′ N., r = –0.823;

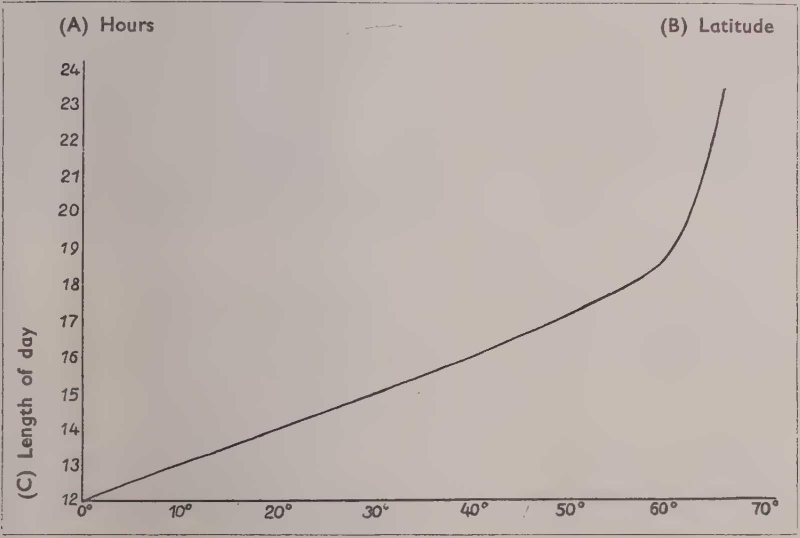
c) for *P. deltoides* whose origins were located between latitudes 31° and 46° the correlation is expressed by r = –0.706.

This means that the more northern the race the more conspicuous is the interaction between latitude and growth. This is partly explained by the fact that changes in climate are greater for every change in latitude toward the north. Diagram 12 shows the correlation between the length of the longest summer day and the latitude. From the equator to 56° N. the longest summer day increases from 12 to 18 hours, but in the next 10° up to 66° N. the summer day increases from as much as 18 to 24 hours. A similar correlation also probably exists between temperature and latitude. The more rapidly the environment changes, the greater are the selection pressures, and the greater is the genetic differentiation to be expected.

Diagram 13, which shows the correlation between growth and latitude in *P. tacamahaca*, closely resembles the curve of summer days in Diagram 12. For the more southern races other causes of variation often compensate for the adaptation to latitude, as is clearly shown in Diagram 14 for *P. trichocarpa*. Here the date when height growth ceases varies considerably in races of the same latitude, particularly when they are of more southern origin.

Probably this latitudinal variation is continuous, with gradual changes in gene frequencies in the populations from south to north; that is, a clinal variation. It might be too schematic merely to speak about photoperiodic variation. It is to be assumed that the selection pressure is exercised primarily by winter cold, which kills biotypes lacking resistance, leaving the more hardy ones. The latter finish their growth early in the autumn, reaching a high degree of maturity. Among the most hardy biotypes, those which are best able to utilize the long summer days during the short vegetative period have a positive selection value.

DIAGRAM 12. – DIAGRAM SHOWING THE CORRELATION BETWEEN LATITUDE AND THE LONGEST DAY OF SUMMER



The general result of latitudinal variation is that northern strains show reduced growth and early defoliation when they are grown to the south of their region of origin.

On the contrary, southern types grown in a more northern region show improved growth and keep their leaves late into the autumn; for example, *P. alba* var. *hickeliana* from Spain and *P. yunnanensis* still have their leaves around 20 November in the north of France. A transfer too far north might, of course, result in reduced hardiness and for this reason many southern clones of *P. deltoides* do not mature well when the growing season is too short, and are caught by the first frosts.

DIAGRAM 13. – DIAGRAM SHOWING THE CORRELATION BETWEEN LATITUDE OF ORIGIN AND DATE OF CESSATION OF HEIGHT GROWTH FOR *P. tacamahaca*, WESTON, MASS. (U.S.A.). PAULEY AND PERRY, 1954

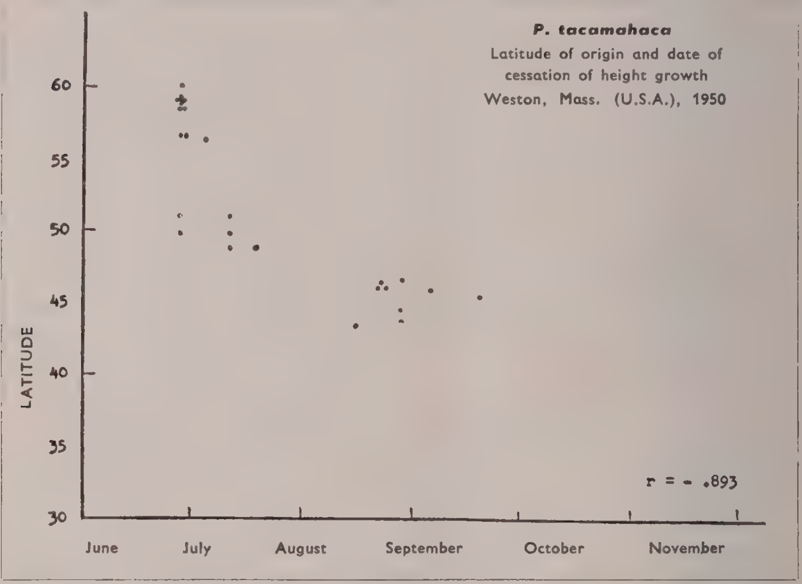
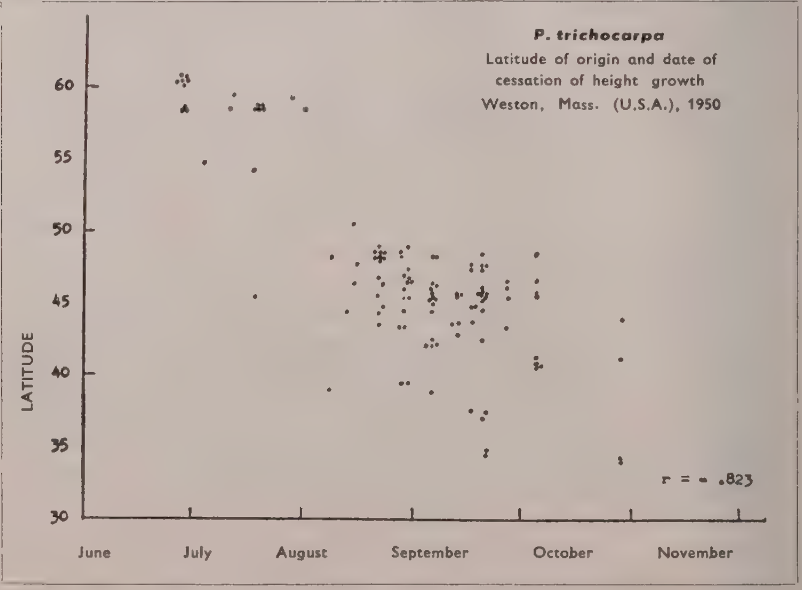


DIAGRAM 14. – DIAGRAM SHOWING THE CORRELATION BETWEEN LATITUDE OF ORIGIN AND DATE OF CESSATION OF HEIGHT GROWTH FOR *P. trichocarpa*, WESTON, MASS. (U.S.A.). PAULEY AND PERRY, 1954



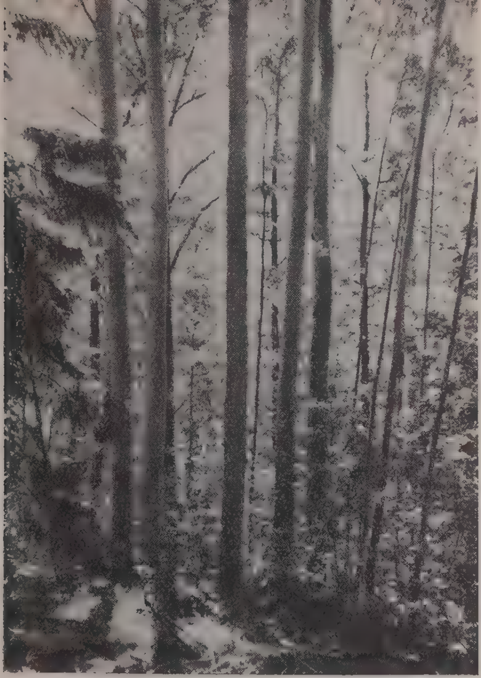


FIGURE 196. – *P. tremula* in central Sweden.

Courtesy *H. Johnsson*

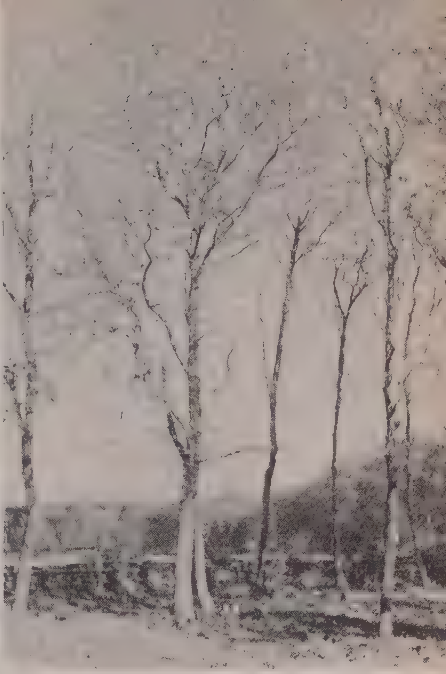


FIGURE 197. – *P. tremula*, a typical variety of southern Sweden.

Courtesy *H. Johnsson*

There are, however, some poplars which thrive far to the north of their original latitude. For instance, *P.* 'robusta' develops very well at latitude 60° N. in Sweden in spite of the fact that one of its parents has its origin south of 50° N. and the other south of 45° N.

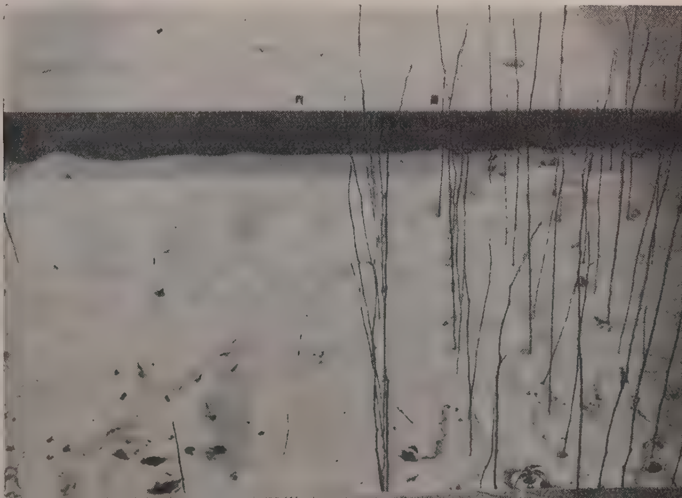


FIGURE 198. – 1-year-old seedlings of *P. tremula*, cultivated in southern Sweden: left, a family of north Swedish origin; right, a family of south Swedish origin.

Courtesy *H. Johnsson*

Variation due to altitude

A parallel variation to that due to latitude is met with in mountainous areas and may be called *altitudinal variation.* Tree populations at high altitudes are hereditarily quite different from populations at low altitudes. At high elevations the biotypes are adapted to short vegetative periods and possess a high degree of winter hardiness, whereas on the plain they often show poor development. Examples are found in *P. tremula* and *P. trichocarpa* and are liable to conceal the influence of latitude.

Resistance to disease

Varying susceptibility to diseases is often conditioned by physiological variability but in this respect interactions of other kinds are involved. Here it suffices to emphasize once again that the interaction between host plant and parasite is a very complicated one from the genetic point of view. It is not only the hereditary variability in the susceptibility of the host that is of importance but also the variability of the pathogen. For instance, *P. tremuloides* is often attacked by *Fusicladium* (*Napicladium*) *radiosum* (*Pollaccia radiosa*) in its native area but is resistant in Sweden, where *P. tremula* is heavily infected. On the other hand, the other North American aspen, *P. grandidentata* is very susceptible to Swedish strains of *Fusicladium.* When the hybrid *P. tremuloides* x *tremula* was brought into cultivation in the nurseries at Ekebo 15 years ago, it was completely resistant to the *Melampsora* rusts. Since then the hybrid has been increasingly attacked each year but is still less attacked than *P. tremula.* Apparently there were already from the outset exceptional *Melampsora* biotypes capable of infecting the hybrid, and with the passage of time these biotypes have propagated themselves more and more, although it is possible that they may have arisen by mutation. The fungi in general seem to have high mutation rates.

Polyploidy

In many phanerogamous plant groups polyploidy has played an important role in evolution. The species of the genus *Populus*, however, all have the same chromosome number, stated by Blackburn and Harrison (1924) to be $2n = 38$. This number has been confirmed for many species by several authors. The corresponding haploid number, $n = 19$, however, is not to be considered as primary but the whole genus must be looked upon as secondary polyploid. Van Dillewijn assumes, on the grounds of meiosis studies, that the basic number is n = 8. The fact that progenies from the cross diploid x triploid *P. tremula* contain aneuploids in unusually high frequencies is also proof that poplars are secondary polyploids.

However, several spontaneous triploid individuals and clones have been found on occasion. Thus, a triploid *P. tremula* was reported in Sweden by Nilsson-Ehle (1956). Later, a fairly large number of triploids was found not only in this species but also in *P. alba* and *P.* x *canescens*. Some of the *P. tremula* triploids are very vigorous trees, as can be seen from Figures 199 and 200. It is to be observed that the triploids in Figures 199 grow near the Arctic Circle. Morphologically, the triploid aspens are characterized by their large leaves (Figure 201) which have earned them the name of *P. tremula gigas* (Nilsson-Ehle).

Some triploid clones have built up fairly extensive stands, propagating themselves by suckers. Investigations in such clonal stands have given results indicating that the triploid aspen has a greater production than that of the diploid. Petrini (1944) has reported the following relation:

	Age years	Remaining stand			Previous fellings	Total production
		Height m.	Diameter cm.	Volume m³/ha.	m³/ha.	m³/ha.
Triploid sample plot	56	23.6	27.7	250.9	153.3	406.2
Diploid sample plot	57	21.2	25.2	142.2	156.2	298.4

Dioeciousness

With the exception of *P. lasiocarpa* which is monoecious, the genus *Populus* is dioecious, apparently with male and female trees in about the same proportion in natural populations. However, exact studies of sex proportions and sex determination have not been made, nor is it known whether sex-linked inheritance occurs. It has been observed, however, that selected plus-trees of *P tremula* and *P. tremuloides* are more often male than female. This fact may indicate that the male trees have better growth and better form than the females in general. It may also be that the sex proportion is not exactly 1 : 1. From the ge-

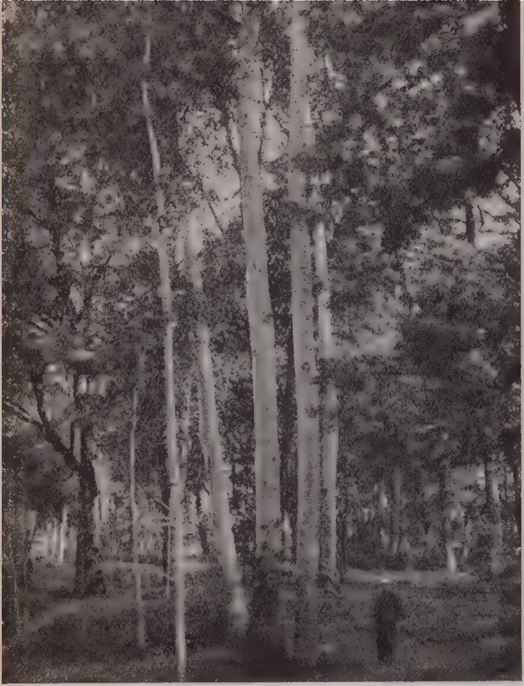


FIGURE 199. – *P. tremula* var. triploid (var. *gigas*), latitude 58° N. in Sweden.

Courtesy *H. Johnsson*

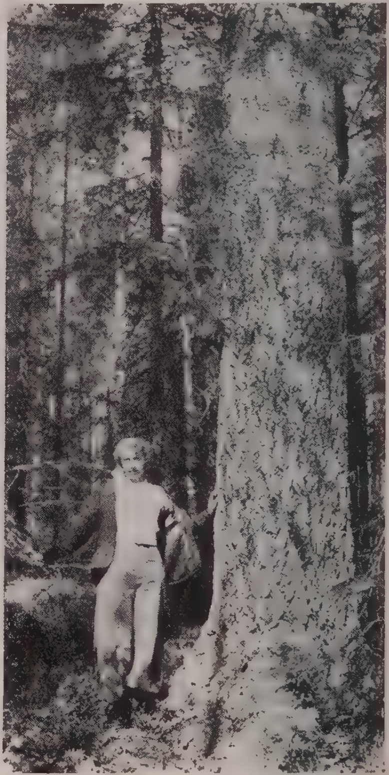
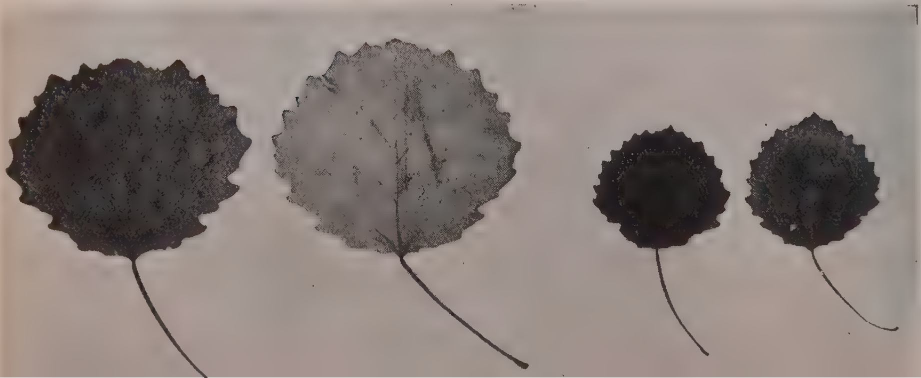


FIGURE 200. – *P. tremula* var. triploid (var. *gigas*), latitude 66° N. in Sweden.

Courtesy *H. Johnsson*

FIGURE 201. – *P. tremula:* left, leaves of the triploid aspen; right, leaves of the diploid aspen.

Courtesy *H. Johnsson*



netic point of view the most important significance of dioeciousness is that the poplars must be obligatory cross-fertilizing allogames. Consequently, every poplar tree is theoretically a hybrid that has arisen from a union of two more or less dissimilar gametes. The likelihood of gene differences becoming homozygous is very slight and every tree must be considered to be heterozygous for a large number of genes, each of which has but little influence compared with the total genotype and the environment. This means that the effect of selection must often be rather limited, but on the other hand that selection, repeated for many generations in the same direction, will give results.

It is self-evident that genetic research and breeding methods, founded on selfing, are inapplicable to dioecious species. As in all dioecious organisms, intersexual individuals also occur in the poplars. In *P. tremula* intersexes of various types are fairly common and have also been found in *P. tremuloides* and *P.* x *canescens*. It has also been possible to raise progenies from selfed intersexes: some of the resulting seedlings were triploid. These progenies sometimes exhibit a pronounced inbreeding depression.

Propagation

It is outside the scope of this chapter to deal with propagation methods but some reference must be made to fundamental facts of importance for genetic studies and breeding. The seed production of poplars is very abundant. The ability to germinate is high but the seed, lacking endosperm, soon loses this capacity for germination. The development of seed from flowering to maturity is very rapid. In nature this process requires about two months, varying somewhat for different species and in different climates. The seed development is particularly fast in the section *Leuce*, which makes it possible to keep cut twigs alive in water culture from dormancy to seed maturity. Under optimal conditions in the greenhouse the seed matures in about one month from dormancy. This method of producing seeds considerably facilitates genetic experiments. In Figure 202, aspen branches are shown in water culture, shedding their seeds.

In the case of black and balsam poplars this method is also possible but more hazardous. With these species it is safer to work with grafted twigs. The method, called bottle grafting, is very practicable. If twigs with dormant flower buds are grafted, the twigs flower after two weeks,

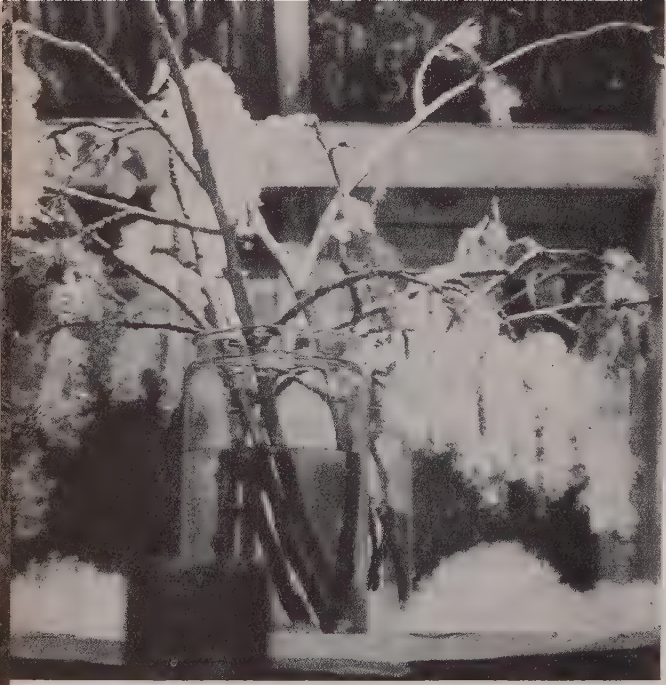


Figure 202. – Cut branches of *P. tremula* in water culture for seed production after artificial pollination.

Courtesy *H. Johnsson*

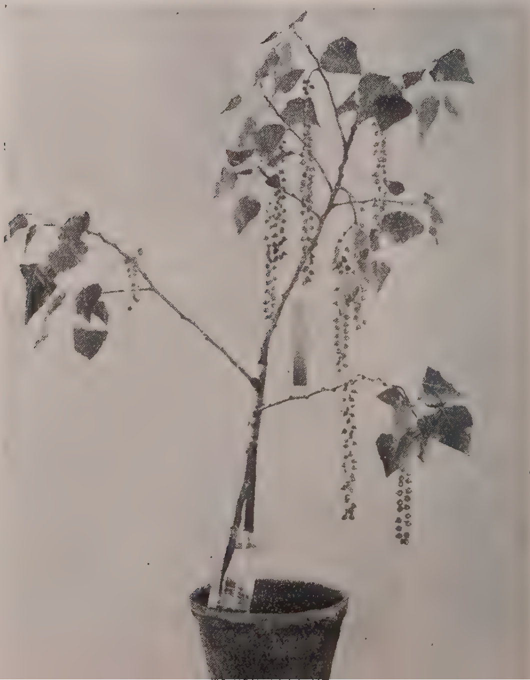


Figure 203. – Bottle graft of *P. nigra* with developing capsules after artificial pollination.

Courtesy *H. Johnsson*

pollination being then effected, the seeds maturing after some time (*see* Figure 203). The grafts, once made, can be cultivated in pots for several years and repeatedly used as stool plants in crossing experiments. Bottle grafts are also useful in the section *Leuce*.

The possibility of propagating poplars vegetatively is of the utmost importance, not only from the silvicultural point of view but also for breeding and genetic studies. In this respect dissimilar sections and species behave very differently. As a rule, black and balsam poplars are easily propagated from dormant cuttings. In general, the rooting is more rapid in balsam poplars. In the section *Leuce*, on the other hand, aspens are unwilling to produce roots on dormant cuttings, whereas in general clones of *P. alba* and even of some of its hybrids can be propagated by such cuttings with fairly good results. The *Leuce* species in the section *Leuce*, however, are capable of suckering, and this property can be utilized in different ways for artificial vegetative propagation. The root cutting method, worked out by Muhle-Larsen (1943), is very efficient if properly conducted. Roots are cut into lengths of about 5 centimeters and cultivated in sphagnum moss in the greenhouse. The root cuttings produce shoots which, when they are about 5 centimeters long, are cut and treated as soft wood cuttings (*see* Figure 204).

Thus, all poplars can be propagated vegetatively in different ways. The genetic significance of this is that any exceptional individual, which is so constituted genetically that propagation by seed is excluded, can be propagated vegetatively on a large scale for reforestation purposes. This means that poplar breeding can be planned as *clone breeding*, and that the simplest technical methods may be used.

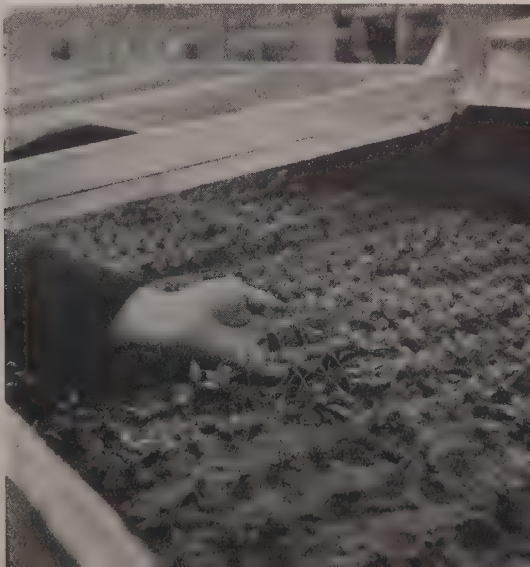


FIGURE 204. – Cuttings from root suckers of *P. tremula* in propagation frame.

Courtesy *H. Johnsson*

II. AIMS OF BREEDING

The aim of all breeding is, of course, to raise strains yielding better economic returns. This aim may be realized by increased quantitative production, by qualitative improvement, or by both. Increase in individual production means a higher rate of growth and shorter rotation periods for the production of timber of certain dimensions. Increase in production per unit area may be attained without increase in individual growth by raising strains which can be grown in denser stands. Of prime importance for quality is the form of the trunk — its straightness and its taper.

Resistance to pathogens and environmental influences play an important role both as regards quantitative production as well as quality of the timber. Thus, selection of less susceptible strains is a necessary link in poplar breeding. It might also be possible to raise forms which are less attacked by insects and higher animals. In cold regions hardy types are essential, and here selection of such forms is the most important factor. To expand the poplar-growing area, it is of value to select forms with lower ecological requirements, which can be cultivated on drier and poorer sites.

The industrial use of poplar wood must also be taken into consideration in breeding. When producing raw material for the chemical industry particular stress must be laid on quantitative production and on cellulose content. If production is to be used mainly for veneers or saw timber, the form of the trunk and the mechanical properties of the wood require increased attention.

It is only natural that in regions with large areas of rich alluvial soil the black poplars should attract most interest, whereas in northern regions with poor moraine soil aspens become the most important species for breeding purposes. White poplars could increase in importance in certain regions, such as the Mediterranean countries, and other poplar species could take a foremost place elsewhere.

III. BREEDING METHODS

Every plant breeding program can be divided into three main operations: *a*) raising a greater number of different strains; *b*) testing these varieties in experimental plantations; and *c*) large-scale propagation of superior varieties. The mode of propagation is always of prime importance. As has already been seen, both generative and vegetative propagation can be used with poplars, the latter being especially applicable to the black and balsam poplars but possible also in the section *Leuce*.

A. SELECTION IN EXISTING POPULATIONS, NATURAL AND CULTIVATED

As regards vegetative propagation, the simplest way to accomplish a breeding program is to select individuals in existing populations, to propagate the selected trees immediately by cuttings on an experimental scale, to test these clones in experimental plantations and, finally, to carry out large-scale propagation of the most satisfactory clones. The populations used for selection may be natural stands within the area of the species, or cultivated stands. The easiest method is to select from natural stands those species which lack spontaneous vegetative propagation, that is, which do not sucker. In such cases there are good reasons to assume that the population is hereditarily adapted to the prevailing climatic and edaphic conditions. If, for instance, the stand is growing in a severe climate, it is reasonable to suppose that the biotypes are hardy. Such advance knowledge is especially valuable if it is intended to use the selected material outside the natural distribution area of the species. When introducing foreign biotypes it is, of course, wise to select them from regions in which the climate corresponds as closely as possible to that of the intended area of cultivation. However, it is advisable not to restrict the region of selection too narrowly. It is possible that the species may be highly adaptable to different climatic and edaphic conditions, and hence the biotypes most suitable for the new area may be found in quite different climates. The chance of finding the desired biotypes increases with the diversity of the material primarily selected.

In populations of this type — natural stands without spontaneous vegetative propagation — it is also to be taken for granted that every tree represents a genotype of its own. Thus, there is no risk of selecting several trees of the same clone. This eventuality must always be taken into account when selecting from natural stands species with natural vegetative propagation as, for instance, *P. tremula* and *P. alba*. Fairly extensive spontaneous clones may occur, and such clones may be rather heterogeneous, particularly in respect of quantitative properties. The clone trees may be of very different ages and may grow on rather different sites. Hence aspens, selected at fairly wide distances from each other and apparently varying morphologically, have turned out in the end to belong to the same clone. On the other hand, the occurrence of clones in natural stands may facilitate the selection, as phenotypical characteristics are more easily observed if possessed by several trees growing side by side. Furthermore, the hereditary nature of such characteristics is strongly indicated by their reappearance within the clone.

Old cultivated stands raised by vegetative propagation give the least guidance for selection. *A priori* there is no knowledge of the climatic zone and ecoformation to which the selected trees were originally adapted, and it must always be remembered that trees selected apart from each other may belong to the same clone. Sometimes observations in experimental plantations over a number of years are necessary in order to solve the problem. Such is the case with the black poplars in Europe. The natural area of *P. nigra* is strongly influenced by cultivation, and the matter is further complicated by introduced American black poplars and their hybrids with *P. nigra*.

It is true, of course, that selection in stands containing a mixture of hybrid clones of unknown geographical origin may give very good results. If the selection is performed in good stands within the area, where the selected clones are later to be used, a certain guarantee is obtained for the biological suitability of the clones within that area.

By means of more or less intentional selection in such stands, most of the widely cultivated forms, for instance *P.* 'gelrica', *P.* 'marilandica' and others, have arisen.

Selection in such stands continues to be widely practiced; it is, in fact, an essential first step in any breeding program undertaken where natural stands are only of minor importance. This is the case throughout western Europe.

B. SELECTION IN ARTIFICIALLY PRODUCED POPULATIONS

Breeding opportunities are by no means exhausted by selection in existing populations. New resources can be established by producing new populations artificially. This can be accomplished in several ways: by means of seed collected in nature, artificial hybridization, raising strains with changed chromosome numbers, and through mutations induced by X-ray or other agencies.

Seed from nature

If seeds are collected in nature and new generations are raised, populations with a wide range of variation may result. In these populations selection can be practiced step by step as the plants and young trees grow.

At the *Istituto di Sperimentazione per la Pioppicoltura*, Casale Monferrato, Italy, this method has been applied for a long time in the following way:

The mother trees are selected in existing stands with special attention to growth rate, good shape of the trunk and crown, commercial value, resistance to disease (particularly spring defoliation), and climatic factors. The female trees selected are to a varying degree hybrids between *P. deltoides*, *P. nigra* and their varieties. The seeds are collected after fertilization has taken place. They thus derive from random pollinations due to crossings at varying distances of male and female trees whose genetic constitutions may be similar or, on the other hand, totally different. As a result, the progenies show a wide range of variation providing excellent opportunities for selection.

Each year the seeds yield in the nursery, without special attention, 5,000 to 100,000 seedlings, which reach a height of 1.50 to 2 meters, and sometimes more, by the end of the first growing season.

At this preselection, only about 5 percent of the best series are chosen for further growth tests. The desirable properties are: a high growth rate, a low incidence of branching, and complete resistance to rust, spring defoliation and other important diseases. The following spring small clones are constituted of the selected seedlings and are grown in the nursery, where they are very carefully observed, particularly for their capacity for rooting from cuttings. A dozen of the best clones are planted a year later in experimental plantations and their development studied over a normal rotation period, that is, 14 or 15 years. The clones which prove superior in this first experimental plantation are reproduced on a larger scale, tested again and, finally, distributed for general use.

This method has yielded a number of improved poplar clones which are being used on an ever-increasing scale in Italy and even elsewhere.

Artificial hybrids

As has already been pointed out, the possibility of raising new fast-growing poplar types by hybridizing different species has attracted much attention, owing to the fact that a number of the cultivated forms represent species hybrids that have arisen spontaneously. These are really hybrids between distant parents, which has been confirmed by meiosis studies and by the fact that they generally give very heterogeneous progenies.

Poplar species belonging to the same section hybridize easily. Crosses between the sections *Aigeiros* and *Tacamahaca* are also highly fertile and give fast-growing hybrids.

Experiments on hybridizations of this kind, carried out by Stout and Schreiner in the United States, have attracted much attention. They tested a large number of interspecific hybrids, particularly between the sections *Aigeiros* and *Tacamahaca*, obtained in 1925-27. After ten years of experiments on their progenies, ten hybrid clones were selected. These are known by the following names: Frye poplar, Strathglass poplar and Rumford poplar (*P. nigra* x *laurifolia*); Roxbury poplar (*P. nigra* x *trichocarpa*), Andover poplar (*P. nigra* var. *betulifolia* x *trichocarpa*), Geneva poplar, Oxford poplar (*P. maximowiczii* x *berolinensis*), Androscoggin poplar (*P. maximowiczii* x *trichocarpa*), Rochester poplar (*P. maximowiczii* x *P. nigra plantierensis*), Maine poplar (*P. candicans* x *berolinensis*).

These poplars are at present being tested in western Europe, where some of them are showing promise. Further experiments are continuing in the United States.

On the other hand, experiments with crosses between the *Leuce* section and black and balsam poplars have given rise to phenomena which are as yet unexplained: crossings between black poplars (American or European) and white poplars from both continents (aspens and gray poplars) give progeny identical to one of the parents. To judge from experience to date, poor growth is to be expected in progenies from crosses between *Leuce* species and species of other sections; the incompatibility is probably very pronounced.

Poplar breeding by means of species hybrids aims in the first place at raising F_1 populations. When breeding strains for vegetative propagation, selection and testing of clones from the selected individuals naturally follows. The intention is to utilize the heterosis, which often accompanies a high degree of heterozygosity. However, it is not sufficient for the hybrids to be heterozygous, they must also possess favorable genotypes; that is, the hereditary constitution of the parents is very important. For this reason the raising of a large number of crosses between different individuals of both the parent species in order to secure as many gene combinations as possible in the F_1 material is recommended.

As balsam poplars in general seem to be more susceptible to certain diseases, such as rust and weeping canker, than the black poplars, and also possess an inferior quality of wood, research should be devoted chiefly to the section *Aigeiros*. This does not mean that balsam poplars should be completely neglected. Promising hybrids between black and balsam poplars have been produced, for instance, from the cross *P. deltoides* x *trichocarpa* (Figure 205).

Even if attention is focused on the F_1 generation, it is by no means out of the question to obtain results by using F_2 and backcrosses, especially

FIGURE 205. – 2-year-old hybrids of *P. deltoides* x *trichocarpa* F_1: left, commercial strains.

Courtesy *M. Larsen*

when vegetative propagation is practiced and thus a single outstanding individual suffices. The F_2 generation from a strongly heterozygous F_1 (a species hybrid) is expected to be highly variable and on the average less vital than the F_1. However, exceptional individuals of great value may be met with. Not only interspecific but also intraspecific crosses may give rise to valuable new populations. If the parents of intraspecific crosses are of widely different geographical origin, heterosis may also be released in such crosses. In any case, it is extremely important that the individuals so crossed should not be selected at random but that they present the maximum qualities possible.

Polyploidy

Polyploid forms have been produced in a great number of plants with the aid of colchicine. For forest tree breeding also, there are good reasons for raising and investigating polyploids, particularly in the vegetatively propagated poplars, since exceptional triploids or aneuploids, impossible to reproduce generatively, can be used. Little is known about polyploid black and balsam poplars. However, a tetraploid black poplar produced by treating the clone *P.* x *euramericana* ' I-154 ' with colchicine, has been reported by the research station at Casale Monferrato. In itself this tetraploid does not seem to be very remarkable. However, it has already produced new, in particular triploid, populations. There are indications that the triploid level is the most promising. A triploid black poplar has been found in the progeny of the cross *P. nigra* x ' robusta ', which has arisen from an unreduced gamete of *P.* ' robusta '. As a hybrid it has an abnormal meiosis and produces diploid gametes, and is an allopolyploid with one genome from *P. angulata*, one from *P. nigra plantierensis* and one from *P. nigra typica*. It is of little value. A polyploid will possess good vitality only if the new chromosome number and the gene constitution interact harmoniously. Such well-balanced combinations between genes and new chromosome numbers may be rather rare. Consequently, it is important to work with as varied material as possible in polyploid breeding.

Tetraploid poplars are produced fairly easily by colchicine treatment. A period of treatment of from one to three weeks, of germinating seeds with 0.1 to 0.2 percent solution gives good results. Mortality is high but the surviving seedlings, though mixoploids in principle, are often fairly pure tetraploids. When the plants are old enough to flower, crosses can be made between different colchicine individuals and between colchicine and diploid trees, giving, on the whole, unlimited opportunities for raising tetraploid and triploid populations of the most varied genic constitution for selection and testing.

Mutation breeding

In order to complete the picture, a few remarks will be made about the theoretical possibilities for making practical use of induced mutations. Spontaneous mutations occur in all organisms in very low frequencies. New mutations are most often recessive, generally having negative effects. Not infrequently they cause pathological symptoms or are lethal (for instance, chlorophyll deficiencies in plants). However, improvements in agricultural plants have been achieved by induced mutations.

Mutations can be induced by irradiation of seeds and shoots by X-ray, fast neutrons, by treatment with mustard gas and in other ways but experiments of this kind with poplars are not known. However, with regard particularly to poplars propagated vegetatively, this method might give results of practical value, as it is possible to utilize a primary somatic mutation which might express itself, for instance, in abnormally thin branches.

C. BREEDING IN CONNECTION WITH GENERATIVE PROPAGATION

The breeding methods outlined above are first and foremost applicable to poplars which are generally propagated vegetatively, that is, poplars belonging to the sections *Aigeiros* and *Tacamahaca*. However, attention must also be paid to poplars of the *Leuce* section, which can be propagated vegetatively, it is true, but for which this mode of propagation cannot unreservedly be considered the most suitable. Breeding by means of seed propagation implies the raising of populations of which a considerable proportion — not only single individuals — must fulfil the necessary requirements, and it must be possible to reproduce these populations generatively.

Selection in existing populations

As far as seed propagation is concerned, selection means the choice of parent trees giving good progenies. Initially the trees are selected for their phenotypical appearance. The selected trees are crossed at random or according to a hypothetical scheme. The progenies are studied in experimental plantations and superior crosses are reproduced on a large scale for reforestation purposes. A necessary requirement for this reproduction is, of course, that the parent trees are still alive at the moment when the progeny test has been completed. In order to ensure this, the parent trees should be propagated vegetatively by grafting or in other ways, when the experimental crosses are made. A few clone plants made from every parent tree are cultivated in an arboretum (" living archives ") and thus preserved for the future. This method of poplar breeding is closely allied to breeding of forest trees in general.

Raising new populations

In the breeding of seed-propagated strains, the raising of new populations by means of intra- and interspecific crosses and by inducing polyploidy, is as important as it is for vegetative propagation.

Interspecific crosses

Certainly all *Leuce* species can be hybridized easily with each other. The following species hybrids are known:

P. alba x *tremula* (spontaneous in nature)
P. alba x *tremuloides*
P. tremula x *tremuloides*
P. tremula x *davidiana*
P. tremula x *grandidentata*
P. tremuloides x *grandidentata* (spontaneous in nature)
P. alba x *grandidentata*

All these combinations are fertile enough to permit the indefinite raising of large F_1 populations. Particular attention has been paid to *P. tremula* x *tremuloides* for more than 20 years on account of its good growth rate. Later, this hybrid was tested and also used for silvicultural plantations on a large scale, especially in Sweden, Denmark and Finland. On the basis of experimental plantations at least ten years old, the following calculations have been made for *P. tremula* x *tremuloides* in comparison with triploid *P. tremula*. The figures are valid for good sites in southern Sweden (Johnsson, 1953):

Rotation period	Years	Mean height	Mean diameter	Total yield per hectare	Mean yield per hectare per year
		m.	cm.	m^3	m^3
P. tremula x *tremuloides*	32	23.7	28.5	520.8	16.3
P. tremula triploid	60	24.0	28.2	443.3	7.4

According to this calculation, *P. tremula* x *tremuloides* can thus be expected to yield twice as much as triploid *P. tremula* per year and unit area during the rotation period.

As has already been pointed out, the result of a species cross is highly dependent on the individual parents. This is demonstrated below by the relative figures for height in a five-year-old experiment including different F_1 families:

Families F_1			Relative height
P. tremula (pure)	Family No.	48-2	60
" "	" "	48-7	71
P. tremula x *tremuloides*	" "	48-12	104
	" "	48-13	89
	" "	48-14	113
	" "	48-15	110
	" "	48-16	105
	" "	48-17	99
	" "	48-18	111
	" "	48-20	111
	" "	48-21	104
	" "	48-23	78
	" "	48-24	101
	" "	48-25	105
	" "	48-26	91
	" "	48-27	87
	" "	48-29	132
	" "	48-31	108

Thus, the lowest hybrid families are only slightly superior to the best *tremula* family but the best hybrid progeny is nearly twice as tall as the best *tremula* progeny. Reciprocal crosses seem to give about the same result, whereas hybrids between *P. alba* and *P. tremula* have been reported to show reciprocal differences with superiority for *P. alba* x *P. tremula*. However, to establish reciprocal differences a large number of crosses in both directions must be compared, in order to eliminate individual variations.

The superior juvenile growth of *P. tremula* x *tremuloides* is not only to be ascribed to true heterosis. Its resistance to *Melampsora* and *Fusicladium radiosum*, inherited from *P. tremuloides*, also plays an important part. Unfortunately, some hybrid populations seem to be susceptible to weeping canker.

As regards seed propagation, derived generations of interspecific crosses are of less immediate interest than in the case of vegetative propagation. Here the average decrease in vitality is of prime importance. A typical case is demonstrated by the following figures for a five-year-old experiment:

Hybrid families		Relative figures for mean height		
		1949	1952	1953
P. tremula		108	111	111
P. tremula x *tremuloides* F_1		114	125	129
P. tremula x *tremuloides* F_2	Family No. 1	98	85	85
	" " 2	76	78	72
	" " 3	104	101	93
Mean total		100	100	100

Polyploid breeding

The occurrence of rare spontaneous triploids in *P. tremula*, and the fact that these autotriploids seem to possess good growth, has already been mentioned. Direct propagation of triploids by seed is impossible because of their irregular meiosis and the production of gametes with varying chromosome numbers. Progenies are obtained, consisting mainly of aneuploids of low vitality, in both crosses between two triploids, and between one triploid and one diploid. Triploid populations, however, can be raised indirectly by crosses of the type tetraploid x diploid. The tetraploid may be obtained by colchicine treatment but other methods also exist. For instance, in progenies from crosses diploid x triploid *P. tremula*, about 1 percent of the plants are tetraploids, derived from unreduced gametes in the triploid. At the Ekebo Institute, the first tetraploid *P. tremula* was obtained from such crosses in 1937. Since 1944, this tree has flowered, and a great number of triploid families have been raised by seed. The ancestry of these triploid populations is as follows:

diploid female x triploid male
offspring with 2n - number varying from 38 to 57
and single tetraploids

diploid female x tetraploid male
triploid populations

These triploid families develop very differently according to their genic constitution but on the whole are rather promising. In an eight-year-old test plantation, the following figures have been obtained for the stand after the first thinning (Johnsson, 1953):

	Mean height m.	Mean diameter cm.	Cubic volume per hectare m^3
Average for 5 triploid families	5.05	4.56	16.3
Average for 3 diploid families	4.07	2.45	12.1

Comparison between vegetative propagation and generative reproduction in the Leuce section

Breeding within the section *Leuce* is, of course, not limited to seed populations, since aspens and white poplars can also be propagated vegetatively in several ways and fairly satisfactorily. It is natural to carry out clone breeding within this section too, applying the same methods as for black and balsam poplars. If such clones are obtained — and they are considerably better than the corresponding seed populations — the higher cost for clone plants is by no means a deterrent. Here the task is to select individuals with an exceptional facility for producing adventitious roots. It would appear reasonable to take advantage of species more inclined to produce adventitious roots, as for instance *P. alba*, and after crossing with this species in F_1 and F_2, to select individuals with extreme properties in this respect. Studies of this kind are now in progress.

IV. TESTING METHODS

There are thus practically unlimited opportunities for producing different poplar strains, consisting of clones or populations. But the next step is to test their value under various growing conditions. This task is by no means easy and, above all, time-consuming.

Field tests

The first requirement of an experimental plantation is that it should be planned in such a way that the validity of the results can be statistically computed. Only randomized experiments in replicates meet this condition. There is a wide choice of arrangements. The latin square is to be recommended when the number of varieties for testing is small (3 to 6). Somewhat larger stocks of up to 10 or 15 varieties may be conveniently arranged in randomized blocks (Fisher) with or without systematic control (Yates) with at least three, or, if possible, more replicates. When the number of varieties is large, one or other design with incomplete blocks is preferable.

The validity of the experiment is also dependent on the number of individuals per plot and on the spacing. It is only natural to start with a large number of varieties, testing them in simpler, preliminary experiments and then to go further with those most promising. If the number of varieties is large, the practical resources available often restrict the size of the plots. Experience has shown that the number of individuals per plot of a clone ought not to be less than 16 (4 × 4), and of a seed population not less than 100.

In the case of preliminary tests, the spacing is determined by the duration of the experiment. As a general rule, the spacing in primary tests should be adjusted so that reliable results are obtained during the first third of the rotation; that is to say, about 8 to 10 years for black poplars in western Europe, and 15 to 20 years for aspens in northern Europe.

Carefully conducted observations of growth, form and other properties during this period should provide sufficient data on which to decide which varieties are most promising for the future and, hence, suitable for testing in larger plantations or perhaps even for their recommendation for immediate silvicultural use. These preliminary tests require a spacing of 3 × 3 or 4 × 4 meters for black poplars, and 1.5 or 2 meters for aspens. Working with new populations raised from seed, in which individuals have been selected for vegetative propagation, it is only natural that a considerable proportion of the seedlings should be discarded after only one or two years and that the full testing program should be carried out with only the very best individuals. In such cases, a complete testing program might be outlined as follows:

1. The whole seed population is cultivated and observed in the nursey for one or more years. Small clones are made of all seedlings in order to facilitate observations and to start propagation on a larger scale.
2. A suitable number of the very best individuals are propagated vegetatively into clones large enough for preliminary field tests.
3. The experimental clones are planted out in field tests with about 16 trees per plot and three replicates. The plantation is arranged according to a suitable design, depending on the number of clones. Spacing 3 × 3 or 4 × 4 meters.
4. When the preliminary plantation is ready for thinning the experiment is considered complete. A few of the best clones are further tested on a semisilvicultural scale.

In all tests, one or two known clones ought to be included as controls. The suitability of using an international standard clone as control could be considered, but, if adopted, a known local clone ought to be included as second control. The plantations and the trees should be treated in accordance with good silvicultural methods, as practiced in the region in question. The growth should be recorded every year for height and diameter, and the volume production per tree and per unit area calculated. When enough data have been accumulated it is worth while trying to extrapolate the future growth by applying the growth function according to Backmann or other correlations. Qualitative characters, resistance and tolerance are recorded, and the observations are statistically analyzed.

If it is possible to test the same clones in several localities with different climatic and edaphic conditions, increased knowledge of the value of the material is, of course, obtained. These fundamental tests must only be exposed to normal risks of infection. Sick trees should be removed. For special testing of resistance, special plantations must be used where artificial inoculation can be carried out.

The test of seed populations can be arranged thus:

1. The whole population is planted out in field tests with about 100 plants per plot, three replicates and a spacing of 1.2 to 2 meters.
2. Thinnings are performed in due course and the experiment is considered complete when one third of the rotation has elapsed. At that time the number of individuals is reduced by 40 to 60 percent.
3. Superior populations are reproduced from seed and final tests are planted out on a semisilvicultural scale. Furthermore, it may be worth while to select the best individuals in the experimental plantations for vegetative propagation or for use as parents in new experiments.

Laboratory tests and nursery observations

For forest tree breeding it would be extremely useful if time-consuming and expensive field testing could be replaced by rapid laboratory tests. Steps have been taken in this direction but it must be admitted, however, that as yet no laboratory methods exist for testing fundamental growth and form properties. In certain respects it ought to be possible to make use of laboratory methods, for instance, in investigating resistance to different fungi and for testing hardiness.

Physiological studies of the water absorption capacity and degree of resistance to dieback have already given interesting results at Freiburg im Breisgau; clones were compared for their drought tolerance by measurement of transpiration, either directly or indirectly, by the autoradiograms of leafy branches obtained after the absorption of radioactive phosphates.

In Switzerland, culture in pots for a two-year period and measurement of the dry weight of roots and the aerial parts of the plants have shown the different behavior of certain *P.* x *euramericana* clones according to their environment. These experiments have also yielded at least relative information on edaphic adaptability of the clones tested (Dr. Richard, Zurich):

Clones tested	Percentage in relation to dry weight obtained in good poplar soil, of the dry weight of aerial parts (p) and roots (r)			
	heavy clayey soil		dry sandy soil	
	p	r	p	r
‘regenerata’ 03–1	57	71	84	103
‘regenerata’ 04–6	74	90	75	82
‘serotina’ 05–6	53	70	76	100
‘serotina’ 06–1	33	42	73	98
‘serotina du Poitou’ 10–1	60	76	67	97

These examples give some idea of the considerable, yet still undeveloped, opportunities provided by these methods.

Nursery observations very closely resemble laboratory methods. Research into rooting capacity is necessary in order to test the stock it is intended to propagate as a clone. Moreover, studies on the growing season which begin at the nursery stage, and on the date when growth starts in the spring and when it ends in the autumn, yield valuable information not only as to the growth rate but also as to hardiness.

FIGURE 206. – Root development of cuttings which have been cut back and planted the second year in three different types of soil.

Above: in compact clay soil; center, in gravelly river sand; below, in “poplar soil.”

Left: clone 06.1 (Basle – *P.* ‘serotina’); center: clone 04.6 (Yverdon – *P.* ‘regenerata’); right: clone 03.1 (Yvonand – P. ‘regenerata’).

Courtesy *E. Marcet*

V. TREE BREEDING INSTITUTES AND ACTIVITIES IN DIFFERENT COUNTRIES

Experiments for raising improved forms of poplars are performed by a fairly large number of investigators at different institutes in many countries. As available details concerning international bodies engaged in this kind of research are very valuable, it was thought that a brief summary of the activities going on in different countries might prove useful. However, as new projects are constantly being started, this list must of necessity be incomplete.

Appendix 1

List of institutes engaged in research on the genetics and breeding of poplars

Austria

Forstliche Bundesversuchsanstalt, Mariabrunn, Wien-Hadersdorf, Dr. W. Wettstein.

Belgium

Institut de populiculture, Grammont, Mr. C. Muhle-Larsen.

Canada

Southern Forest Experiment Station, Maple, Ontario, Dr. C. Heimburger.

Czechoslovakia

The Institute for Silviculture and Forest Biology of the State Research Institutes, Brno, Dr. G. Vincent.

Denmark

Arboretet, Hørsholm, Dr. C. Syrach Larsen.

Finland

The Foundation for Forest Tree Breeding, Klemetskog, Korso, Mr. M. Hagnan.

France

Station de recherches et expériences forestières de l'Ecole nationale des eaux et forêts, Nancy.

Germany, East

Institut für Forstwissenschaften Eberswalde, Zweigstelle Waldsieversdorf, Waldsieversdorf, Dr. O. Schröck.

Institut für Forstwissenschaft Tharandt, Zweigstelle Graupa, Graupa, Dr. H. Schönbach.

Germany, West

Bundesanstalt für Forst- und Holzwirtschaft, Abt. Forstgenetik und Forstpflanzenzüchtung, Schmalenbeck über Ahrensburg, Dr. W. Langner and colleagues.

Württ. Forstl. Versuchsanstalt, Abt. Botanik und Standortskunde, Stuttgart, Prof. G. Schlenker.

Wissenschaftliches Institut des Deutschen Pappelvereins, Brühl bei Köln, Dr. R. Müller.

GREAT BRITAIN

Forestry Commission, Forest Research Station, Alice Holt Lodge, Farnham, Mr. T. R. Peace and Mr. Mathews.

ITALY

Istituto di Sperimentazione per la Pioppicoltura, Casale Monferrato, Prof. G. Piccarolo and colleagues.

JAPAN

Tokyo University Forest, Yamabe Sorachi, Hokkaido, - Dr. N. Takahashi.

NETHERLANDS

Institute of Forestry of the Agricultural University, Wageningen, Prof. G. Houtzagers.

The Netherlands Forest Research Station, Wageningen, Dr. H. van Vloten.

NORWAY

The Institute of Silviculture at the Agricultural College of Norway, Vollebekk, Mr. M. Haugberg.

SWEDEN

Forest Tree Breeding Institute, Ekebo, Källstorp, Dr. H. Johnsson.

Dr. E. Uggla, Mykinge Research Farm, Lyckås-gård.

SWITZERLAND

Eidgenössige Anstalt für das forstliche Versuchswesen, Zürich, Dr. F. Fischer.

Eidgenössige Technische Hochschule, Zürich; Institut für Waldbau, Dr. E. Marcet.

UNITED STATES OF AMERICA

Maria Moors Cabot Foundation for Botanical Research, Petersham, Mass., Dr. Scott S. Pauley.

Northern Experiment Station, Upper Darby, Penn.; Lake States Forest Experiment Station, St. Paul.

The Institute of Paper Chemistry, Appleton, Wisc., Dr. Ph. N. Joranson.

THE CHARACTERISTICS OF POPLAR WOOD, ITS EXPLOITATION AND UTILIZATION

Poplar wood has for several centuries been put to a wide variety of uses but, whereas studies have long been carried out on other species such as spruce, fir, larch or beech, this has not been the case with poplar, and even as late as 1946-47 very little precise information was available on the subject.

The chief reasons for this neglect are to be found in the fact that the poplar has rarely been considered a true forest species, or at any rate not an important one. The ever-increasing needs of the inhabitants of regions lacking forests and the demands made by certain recently developed industries, such as the match and packaging industries, have brought the species to the fore in spite of the low regard in which it was held in certain forestry circles.

From the very first meetings of the International Poplar Commission it became clear that there was a deplorable lack of detailed information on the timber of the very tree whose cultivation it was planned to promote. The Commission therefore took steps to establish, in collaboration with the Wood Technology Committee of FAO, a " test form " to ensure the uniformity and comparability of information collected on poplar wood.

This form (*see* Appendix 1), which was drawn up at the first meetings of the Commission, is always subject to amendment. It has since been supplemented by a form giving instructions on how to take samples (*see* Appendix 2).

The Commission also took steps to draw up standard industrial tests for the purpose of obtaining comparable results, and studies are now being undertaken on the basis of a method developed by the research section of the *Centre technique du bois*, Paris.

In addition, the Commission, which has stipulated in its statutes that timber producers and users must both be represented in national poplar commissions, has often emphasized the need for countries to include in their delegations representatives of the utilization industries, in order to give the work of the Commission the equilibrium needed to attain its aims. It is, for example, totally useless for foresters to continue to plant clones whose timber cannot be profitably used; they should, on the other hand, be in touch with the needs of the industry so as to be in a position to provide — within biological and ecological limits — the products required.

Hence the *raison d'être* of this chapter on the characteristics of poplar wood, its exploitation and utilization, lies in the recognized need for close liaison between research into biological factors and cultural techniques on the one hand, and wood utilization and the general economy of the consumer industries on the other.

The first part of this chapter deals with the characteristics of poplar wood. An attempt has been made to assemble all the available data from literature, together with the results of special studies carried out on a series of samples originating in several countries. In general, in spite of differences in origin, poplar wood shows remarkable uniformity in its structural characteristics; this is not, however, borne out by comparable behavior when put to different uses. Even within the same country, timber from different poplar types showing no appreciable variation under macroscopic and microscopic examination, can in its practical application vary widely in suitability, chiefly as a result of its manner of growth.

Site factors are examined in detail in the second section, which is devoted to the defects of poplar wood. Their importance and origin should be known if an effort is to be made to prevent these defects and thus obtain timber of quality.

The third section deals with felling and extraction in poplar stands, and the fourth section with the utilization of the wood. It will be noted that these last two parts give details referring to selected countries. While this information may not be valid in its entirety for other regions, it can nevertheless provide a very useful guide, particularly if the physical, technical and economic conditions of the site are similar.

In order to provide detail as complete as possible on the still little known subject of utilization, it has been thought useful in the sections which follow to include the characteristics of poplar types which are still imperfectly known, even if they have not been accurately identified.

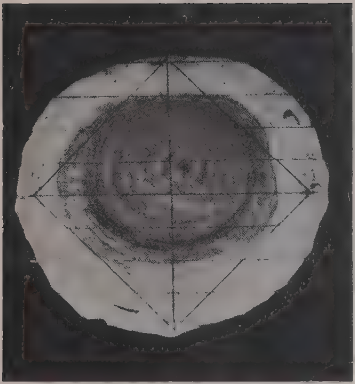


Figure 207. – Cross section of a Euramerican hybrid after felling, showing strong coloration of the core.

Courtesy *Istituto Casale Monferrato*

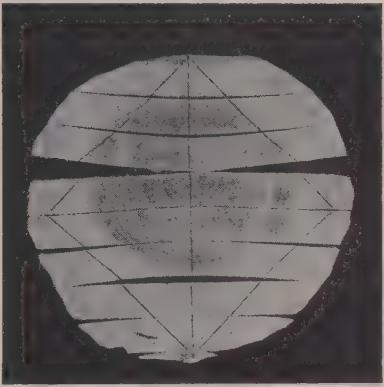


Figure 208. – The same bole several weeks after it had been sawn into planks and seasoned. The color has faded. Note the normal warping of the planks.

Courtesy *Istituto Casale Monferrato*

I. CHARACTERISTICS OF POPLAR WOOD

A. Macroscopic appearance

Color, sapwood, heartwood

The basic color of poplar wood is ivory white for *P. alba*, *P. tremula* and their hybrids; yellowish white for *P. nigra* and the Euramerican hybrids; yellowish white with light red or reddish tints for *P. euphratica*; yellowish white for *P. tremuloides*; white for *P. deltoides*, *P. tacamahaca* and *P. heterophylla*; grayish white for *P. ciliata*.

Fairly often the color is different in the central part of the wood, although this is not necessarily a definite sign of duraminization or change from sapwood to heartwood, except in the case of *P. alba*. When the latter reaches a certain age, its duraminization is shown by a yellowish or reddish brown coloration, with the edge very often sinuous and marked by a yellow, gummy secretion, which will be discussed later. This phenomenon frequently occurs also in *P. alba* hybrids, for example *P.* x *canescens*. Similar secretions have been reported for *P. ciliata* Wall. of the Himalayan range and *P. maximowiczii* of Japan. In *P. tremula* the heartwood is usually not tinted; in *P. euphratica* it may be reddish; in *P. nigra* it is sometimes a brown color, while in *P. deltoides*, *P. hetero-*

phylla and the Euramerican hybrids the interior of the stem, when felled, is frequently a bronze color, sometimes with brown and sometimes gray-green hues. This phenomenon is not accompanied by the formation of tyloses but is linked with a high water content in the tissues (which will be discussed later). On seasoning, the color fades, without however completely disappearing. Attacks by fungi, insects and bacteria can produce changes in the normal color of the wood. Oxidation of the sap also leaves blemishes which detract from the value of the wood.

The planed surface of nearly all seasoned poplar wood has a certain luster, provided it is not abnormal wood (e. g., tension wood).

Odor

Unseasoned poplar wood has a stale, almost nauseous odor which is particularly marked in some Euramerican hybrids with a pronounced bronze heart; when the wood is seasoned, this odor disappears entirely. By contrast, the heartwood of *P. alba* has a disagreable, almost pungent odor, due to the yellow gum mentioned earlier. This odor persists, though not as strong, in the seasoned wood which, for this reason, is highly prized for furniture in some regions, as it repels insects.

Texture and grain

Unless the tree has been injured, poplar wood is usually even-textured. Some black poplars, however, show at the base of the trunk an entanglement of fibers of a marked wavy grain. The very small size of the fibers produces a rather fine grain.

Annual growth rings

They can be made out clearly enough in transverse sections, though there is no difference in color between the initial and the final wood; in temperate regions they correspond to an annual layer. Their width depends on the tree's growth and may vary within rather wide limits. Whereas in the north European strain of *P. tremula* the rings may be barely a few millimeters wide, in the Po Valley, Euramerican hybrids such as the ' I-214 ' are often found to have rings of 30 millimeters. Sometimes the rings do not form regular circles but appear as rather pronounced undulating lines, as can be detected on the surface of the bole under the bark.

In longitudinal sections, the growth rings are not always easy to distinguish.

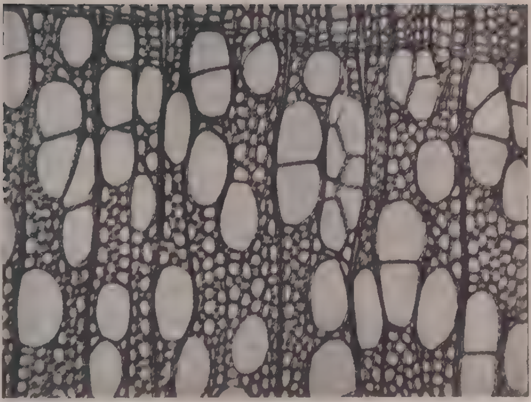


FIGURE 209. – Transverse section of *P. tremula* (x 85).

Courtesy
Istituto Nazionale del Legno, Florence

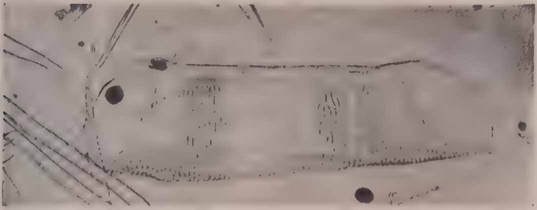


FIGURE 210. – An isolated vessel (*P. euphratica*) with three rows of pits connecting it with the parenchyma cells of the rays (x 90).

Courtesy
Istituto Nazionale del Legno, Florence

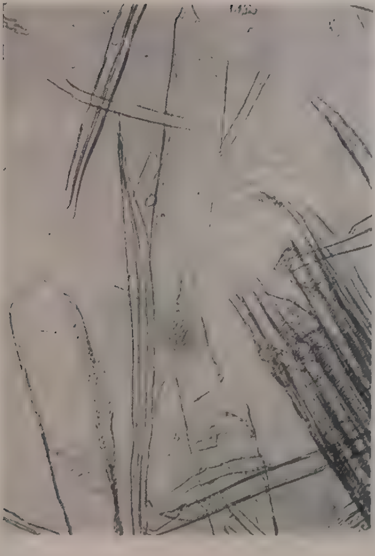


FIGURE 211. – Vessels, fibers and parenchyma cells of *P. nigra* (x 85)

Courtesy
Istituto Nazionale del Legno, Florence

B. MICROSCOPIC APPEARANCE

Poplar wood is made up of a water-conducting vascular tissue, a mechanical or supporting tissue of fibers, and a storage tissue of parenchymatous cells.

Conducting tissue

The vessels are straight and formed of cells averaging 0.39 to 0.61 millimeters in length, with a length: diameter ratio of 2 : 13. These cells have single perforations at the ends, inclined at an angle varying between 10° and 70° to the axis, usually at about 45°. The extremities are sometimes rather tapered. The vessels are evenly distributed in the annual layer but are not grouped in any special arrangement; they may be isolated or in radial rows of two to seven joined components (it is unusual for there to be more than four). Their frequency, that is, the number of vessels per square millimeter of transverse section, varies within a single species between the limits indicated in Table 14.

The transverse section of vessels is oval; further details are given in Table 15.

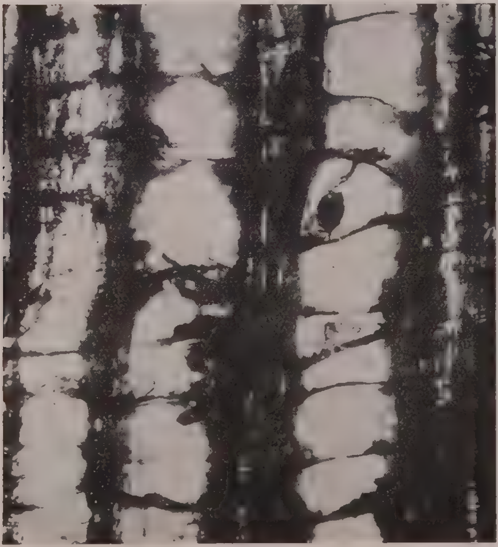


FIGURE 212. – Vessels of *P. alba* (x 65).

Courtesy ***Istituto Nazionale del Legno, Florence***

TABLE 14. – NUMBER OF VESSELS PER MM² OF WOOD

Type	Initial wood	Final wood	Average no. of vessels
P. alba (Piedmont plain)	55	111	82
P. alba 'Roumi' (Syria)	61	92	73
P. tremula (Piedmont plain)	60	90	75
P. tremula (Piedmont mountain)	121	186	146
P. hybrida * (Iran)	51	62	56
P. nigra (Cyprus)	64	79	72
P. nigra 'Blanquillo de Granada' (Spain)	50	101	69
P. nigra 'Hamoui' (Syria)	83	98	86(+)
P. nigra 'Farsi' (Syria)	68	85	67(+)
P. nigra 'Spindar' (Iraq)	131	148	125
P. nigra 'Phräss' (Kashmir)	81	80	76
P. x *euramericana* (Italy) (Switzerland) (Germany)	35 — —	71 — —	48 36–60 58–73
P. x *euramericana* 'Chopa de Granada' (Spain)	26	47	31
P. x *euramericana* 'Negrito de Granada' (Spain)	42	64	50
P. x *euramericana* 'Pinseque de Zaragoza' (Spain)	56	60	60
P. euphratica (Syria)	45	112	80
P. euphratica (Iraq) heartwood sapwood	57 45	74 57	58 48
P. ciliata (Punjab)	67	69	66

* According to BIEB.

+ The average for the whole growth ring which is lower than the arithmetical mean of the highest and lowest figures, is obtained from a smaller number of vessels in the middle part of the stratum.

(The above figures, with the exception of those for Switzerland and Germany, were provided by L. Demi of the *Istituto Nazionale del Legno*, Florence).

TABLE 15. – DIAMETERS OF VESSELS
(unit = micron)

Type	Initial wood		Radial diameter/ tangential diameter	Final wood		Radial diameter/ tangential diameter
	radial diameter	tangential diameter		radial tangential	tangential diameter	
(according to L. DEMI)						
P. alba (Piedmont plain)	46–92	30–76	1.50	30–46	23–38	1.27
P. alba ‘ Roumi ’ (Syria)	102–143	49–102	1.59	41–123	41–82	1.26
P. tremula (Piedmont plain)	107–146	53–76	1.76	30–92	38–76	1.01
P. tremula (Piedmont mountain)	35–228	71–128	1.44	57–142	49–85	1.36
P. hybrida * (Iran)	62–148	33–111	1.46	45–103	25–74	1.50
P. nigra (Cyprus)	128–220	71–157	1.55	50–171	50–114	1.37
P. nigra ‘ Blanquillo de Granada ’ (Spain)	57–135	49–123	—	29–61	29–66	—
P. nigra ‘ Hamoui ’ (Syria)	61–108	54–77	1.38	23–69	31–46	1.12
P. nigra ‘ Farsi ’ (Syria)	61–184	61–123	1.52	41–123	41–74	1.32
P. nigra ‘ Spindar ’ (Iraq)	25–131	32–94	1.24	37–74	37–66	1.06
P. nigra ‘ Phräss ’ (Kashmir)	82–173	70–123	1.34	29–103	41–103	1.00
P. x *euramericana* ‘ I-214 ’	94–246	41–135	1.60	37–115	41–86	1.17
P. x *euramericana* ‘ Chopa de Granada ’ (Spain)	98–205	78–139	—	45–78	37–78	—
‘ Negrito de Granada ’ (Spain)	62–139	57–98	—	37–103	33–74	—
‘ Pinseque de Zaragoza ’ (Spain)	41–123	21–78	—	25–74	29–66	—
P. euphratica (Syria)	100–300	71–174	1.60	36–86	35–87	1.20
P. euphratica						
(Iraq) heartwood	62–123	49–103	1.22	37–76	33–57	1.14
sapwood	57–189	57–130	1.34	57–103	33–78	1.28
P. ciliata (Punjab)	86–139	69–98	1.27	33–102	49–87	1.00

* According to BIER.

The common walls of adjoining vessels have oval or slightly hexagonal, bordered pits with a contracted oval orifice. The orifice may, however, be octagonal in shape as in *P. euphratica*, or with an irregular contour as in *P. nigra*. The pits are arranged in slanting rows and vary in number between 6,500 and 7,500 per square millimeter of wall: the diameter is from 14 to 21 microns. At the same level as the parenchymatous cells of the medullary rays, the walls of the vessels have simple oval pits arranged in horizontal rows. In the interior of vessels of *P. alba*, in the region of the duramen, tyloses can be seen which are so numerous, and stretched to such an extent, that they have lost their globular shape and become cylindrical, occupying the entire vessel cavity. The vessels also contain droplets of yellow, transparent gum which have the following characteristics:

density: 1.6

complete solubility:	in 1% acetic acid in 1% caustic soda (NaOH) in absolute ethyl alcohol
partial solubility:	in hot water (100°) and in cold water
insolubility:	in ethyl ether in xylene

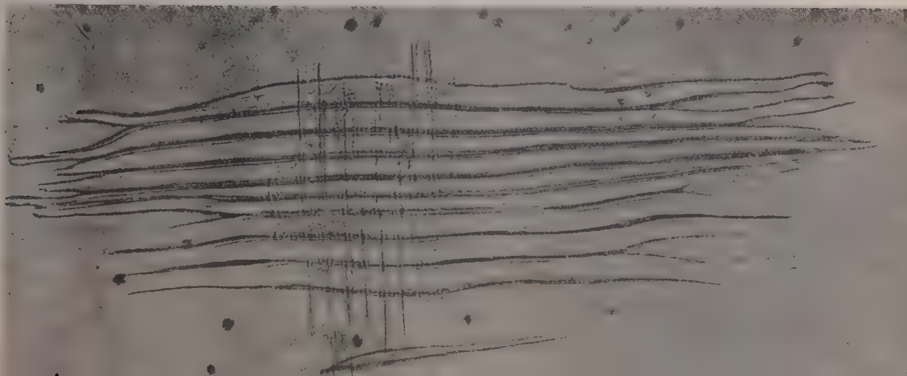
The conducting tissue constitutes 20 to 30 percent of the ligneous tissue. But if the area occupied by the vessels in a transverse section is taken into account, from a minimum of 15 percent in the final wood, one arrives at 42 percent in the initial wood.

Mechanical tissue or fibers

The mechanical tissue is formed of fibers having walls that are thin in proportion to their diameter. Table 16 shows their general characteristics and their variations according to the position in the bole.

FIGURE 213. – Fibers and parenchyma of a medullary ray of *P. alba*.

Courtesy *Istituto Nazionale del Legno, Florence*



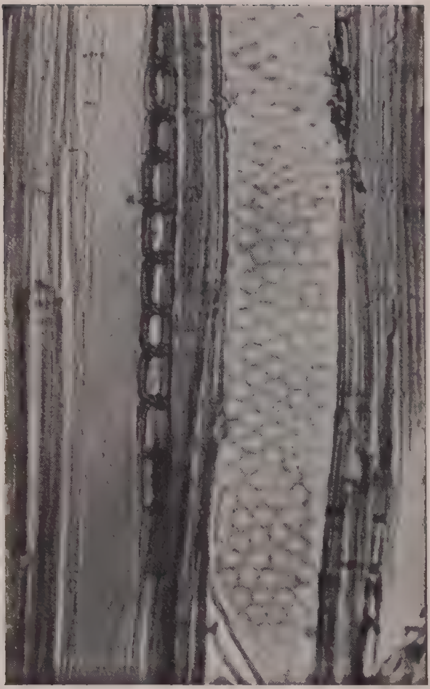


FIGURE 214. – Tangential section of *P. tremula*, showing homogeneous rays and vessels with oval pits (x 275).

Courtesy *Istituto del Legno, Florence*

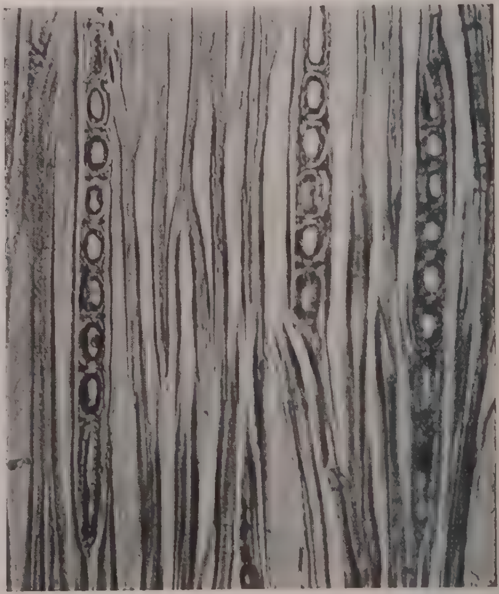
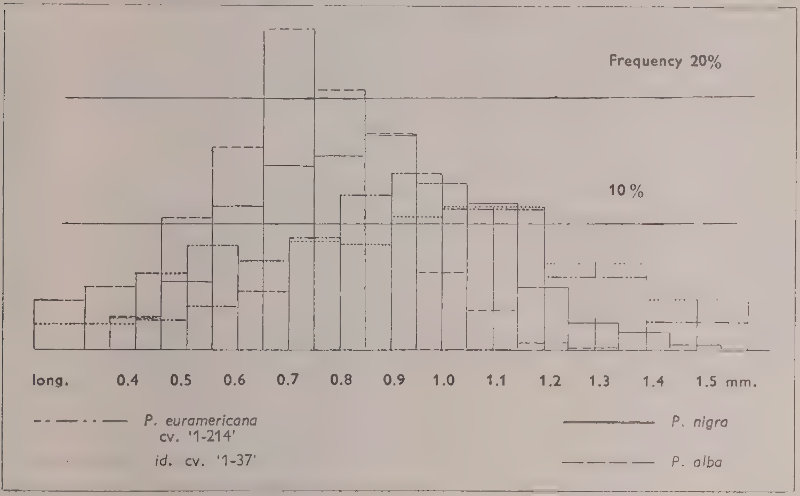


FIGURE 215. – Tangential section of *P. euphratica*, showing rays with heterogenous cells (x 320).

Courtesy *Istituto Nazionale del Legno, Florence*

DIAGRAM 15. – DISTRIBUTION OF FIBERS ACCORDING TO LENGTH (BASED ON MEANS OF FIGURES SUPPLIED BY BOESSNECK, BROSSA AND VIVIANI FOR *P. nigra* AND *P. alba* AND ON TESTS CARRIED OUT AT THE CARTIERE BURGO FOR *P.* x *euramericana* cv. '1-214' and cv. '1-37').



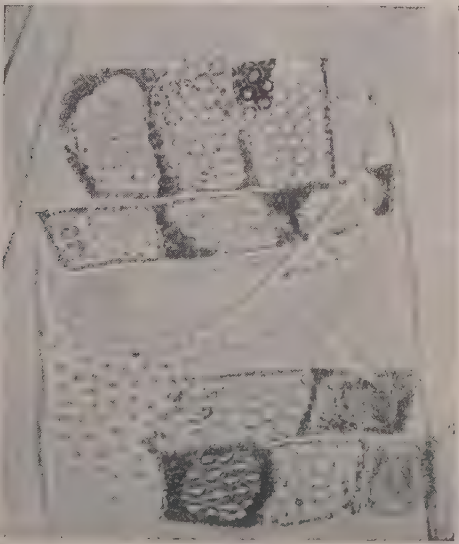


FIGURE 216.– Detail of heterogeneous cells in a medullary ray of *P. euphratica* (x 270).

Courtesy *Istituto Nazionale del Legno, Florence*

Very small pits with elongated crossed orifices at an angle of 30° to 35° to the axis can be seen on the fiber walls. These pits are not evenly distributed but predominate in the radial walls. Other pits, slightly larger, occur in the area where the fibers cross the parenchymatous cells of the medullary rays. The fibers are not all identical at the same height from the ground and in the same annual ring, since the cell walls in the summer layer are thicker. Lastly, at the end of the stratum, two or three rows of fibers are contracted and are quite different from the others.

The fibers of *P. ciliata* sometimes contain calcium oxolate crystals. Mechanical tissue forms 56 to 79 percent of the whole tissue.

Parenchymatous tissues

Most of the parenchyma cells are grouped in the medullary rays which are not visible individually to the naked eye. In the aggregate, the latter impart to the radial sections a certain appearance of silkiness.

These rays, in a homogeneous but not tiered arrangement, generally consist of a single row of cells; nevertheless, it is possible in certain cases (notably *P. euphratica*) to find two rows of cells which together are no wider than the other cells in the ray. In a longitudinal direction, the rays are formed by a super-position of parenchyma cells orientated in a horizontal direction from the pith outward: the length of the cells is almost double the transverse dimension of 20 to 46 microns. The number of cells and the heights and widths of the medullary rays are given in Table 17.

A very important characteristic of poplar wood, by which it can be identified, is the homogeneity of the cells which make up the medullary rays, identical at the ends and in the center (the ray cells of wood of *Salix*, which greatly resembles that of poplar, are heterogeneous). While the homogeneous character of the rays is constant in *P. nigra*, *P. alba*, *P. tremula* and the Euramerican hybrids, it is not true in the case of *P. euphratica* and *P. angustifolia*, in which the end cells and even the middle cells are often higher than they are long. Since the leaves of these two poplars are similar to those of willows (a youthful form in the case of *P. euphratica* but permanent in *P. angustifolia*), it would appear possible that they are transitional species between the two genera.

The transverse dimension of the parenchyma cells of the rays is slightly smaller than that of the fibers; it follows that the area of intersection is rectangular; the pits are simple and unevenly distributed. In the areas where the end cells of the rays intersect with the vessels there are still on two to four rows, oval or subrectangular, round-cornered pits. These

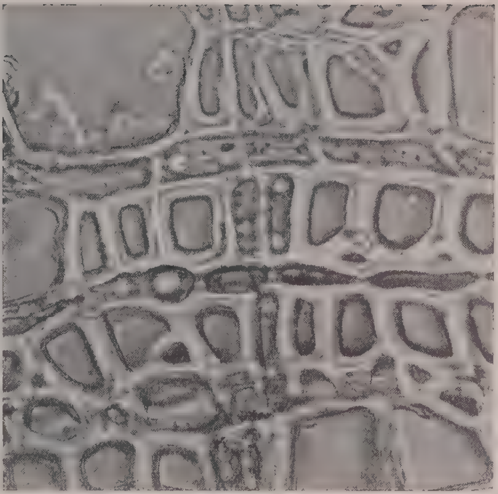


FIGURE 217. – Parenchymatous cells situated between the final wood of one year and the initial wood of the following year (x 440).

Courtesy *G. Giordano*

pits are less frequent in the areas of intersection with the cells of the central part of the ray.

Inside the parenchyma cells of the rays are found starch granules: in the case of *P. alba*, when duraminization is in progress, there are accumulations of gum, as has already been mentioned, and for *P. euphratica*, yellow droplets.

As well as the parenchymatous tissue of the rays, there are also storage cells between the fibers and, more precisely, at the point between the summer layer of a growth ring and the new spring layer of the following year.

The parenchymatous tissues form 3 to 10 percent of the ligneous tissues.

Medullary spots

Such spots or flecks are not frequent but do occur, chiefly as a result of attack by certain insects (*Agromiza*).

C. PHYSICAL AND MECHANICAL CHARACTERISTICS

Density and porosity

The density of wood depends on two factors: its porosity when dry (that is, the ratio between the volume occupied by air inside the cell cavities and the external volume of the test specimen) and its moisture con-

DIAGRAM 16. – VARIATIONS IN THE DENSITY OF GREEN AND SEASONED WOOD ACCORDING TO FELLING SEASON, HEIGHT AND ANNUAL RING IN A STEM OF *P.* x *euramericana* cv. ‘ I-214 ’

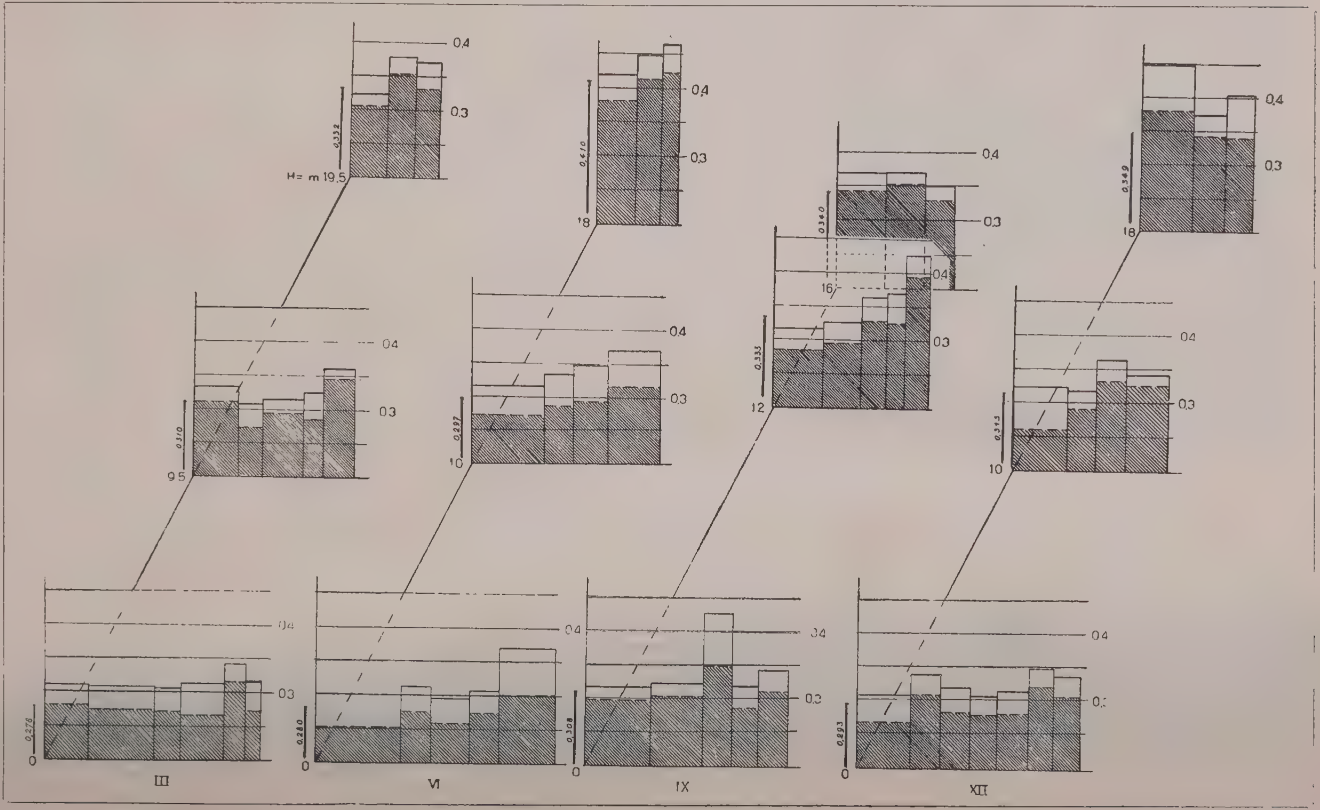


TABLE 16. – FIBER DIMENSIONS

Types	Length of fibers in mm.			Diameter of fibers in mm.		Length/diameter ratio	Thickness of fiber walls (in microns)
	max.	average	min.	max.	min.		
P. alba (Boessneck, Brossa, Viviani)							
at base, sapwood	1.29	0.84	0.45				
at base, heartwood	1.21	0.76	0.41				
at mid-height, sapwood	1.11	0.72	0.40				
at mid-height, heartwood	1.00	0.70	0.41				
at top	1.05	0.68	0.41				
P. alba (Piedmont plain) (Demi)							
heartwood: initial wood	1.77	1.24	0.96	0.045	0.020	39	—
heartwood: final wood	2.01	1.39	0.98	0.041	0.020	32	—
sapwood: initial wood	1.52	1.13	0.80	0.049	0.020	36	3.36
sapwood: final wood	1.88	1.41	0.97	0.049	0.029	37	4.42
P. alba 'Roumi' (Syria) (Demi)							
initial wood	1.77	1.30	0.74	0.045	0.020	41	4.20
final wood	1.95	1.21	0.78	0.045	0.020	40	5.65
P. alba (Kashmir) (Demi)	1.82	1.21	0.65	0.055	0.025	36	4.88
P. tremula (Hagglund)	1.70		0.80	0.046	0.020	—	—
P. tremula (Piedmont plain) (Demi)							
initial wood	1.26	0.84	0.47	0.038	0.008	40	4.65
final wood	1.30	1.01	0.70	0.038	0.008	44	6.25
P. nigra (Cyprus) (Demi)							
initial wood	1.29	0.91	0.57	0.032	0.015	46	5.40
final wood	1.47	1.01	0.51	0.032	0.015	44	6.15
P. nigra 'Hamoui' (Syria) (Demi)							
initial wood	1.41	0.99	0.54	0.032	0.015	45	5.45
final wood	1.35	1.01	0.54	0.038	0.015	47	6.35
P. nigra 'Farsi' (Syria) (Demi)							
initial wood	1.50	1.20	0.69	0.057	0.029	29	5.15
final wood	1.68	1.06	0.47	0.057	0.025	24	5.20

TABLE 16. – FIBER DIMENSIONS *(continued)*

Types	Length of fibers in mm.			Diameter of fibers in mm.		Length/diameter ratio	Thickness of fiber walls (in microns)
	max.	average	min.	max.	min.		
P. nigra 'Spindar' (Iraq) (Demi)							
initial wood	1.43	1.10	0.67	0.038	0.020	41	5.55
final wood	1.56	1.24	0.59	0.042	0.017	38	6.35
P. nigra 'Phräss' (Kashmir) (Demi)							
initial wood	1.39	1.01	0.61	0.045	0.025	31	5.10
final wood	1.45	1.08	0.45	0.042	0.025	35	4.67
P. nigra (Boessneck, Brossa, Viviani)							
at base, sapwood	1.49	0.90	0.40				
at base, heartwood	1.21	0.68	0.30				
at mid-height, sapwood	1.39	1.00	0.45				
at mid-height, heartwood	1.40	0.89	0.52				
at top, sapwood	1.60	0.87	0.40				
at top, heartwood	1.15	0.81	0.45				
P. x *euramericana* cv. 'I-214' (Scaramuzzi)							
at base	1.90	1.17	0.53	—	—	36	3.46
at 9.5 m.	2.16	1.11	0.41	—	—	36	3.78
at 19.5 m.	1.66	1.03	0.57	—	—	36	3.92
P. x *euramericana* cv. 'I-37'		0.92					
(Cartiere Burgo) cv. 'I-455'		0.76					
cv. 'I-476'		0.93					
cv. 'I-488'		0.87					
cv. 'I-154'		0.76					
P. euphratica (Syria) (Demi)							
initial wood	1.87	0.91	0.52	0.054	0.015	42	4.3
final wood	1.90	0.90	0.52	0.031	0.007	48	5.8
P. euphratica (Iraq) (Demi)							
heartwood: initial wood	1.15	0.92	0.57	0.030	0.015	39	5.57
heartwood: final wood	1.21	1.06	0.61	0.035	0.017	39	5.92
sapwood: initial wood	1.67	1.28	0.85	0.042	0.025	37	5.00
sapwood: final wood	1.49	1.14	0.80	0.045	0.025	34	5.20

TABLE 16. - FIBER DIMENSIONS (*concluded*)

Types	Length of fibers in mm.			Diameter of fibers in mm.		Length/diameter ratio	Thickness of fiber walls (in microns)
	max.	average	min.	max.	min.		
P. ciliata (Punjab) (Demi)							
initial wood	1.76	1.18	0.52	0.052	0.025	32	5.52
final wood	2.04	1.36	0.70	0.050	0.022	40	5.65
Average figure on the basis of sulphate pulp (Jayme)							
P. trichocarpa (Jayme)		1.003					
P. tremula villosa (Jayme)		0.909					
P. x *euramericana* cv. ' grandifolia ' (Jayme)		0.987					
P. x *euramericana* cv. ' robusta ' (Jayme)		1.022					
Average figure on the basis of 45 different types of sulphate pulp (Jayme)		0.930					
P. x *euramericana*							
' Chopa de Granada ' (Demi)							
initial wood	1.86	1.28	0.56	0.055	0.028	33	5.52
final wood	2.23	1.45	0.22	0.053	0.015	43	6.05
' Pinseque de Zaragoza ' (Demi)							
initial wood	1.32	1.01	0.60	0.035	0.018	39	4.96
final wood	2.05	1.18	0.87	0.030	0.015	38	4.25
' Negrito de Granada ' (Demi)							
initial wood	1.376	1.000	0.595	0.045	0.023	30	4.23
final wood	1.897	1.441	0.856	0.035	0.020	50	5.38
' Canada de Bordils ' (Demi)	2.08	1.38	0.65	0.050	0.018	46	4.74
P. nigra ' Blanquillo de Granada ' (Demi)							
initial wood	1.08	0.77	0.46	0.035	0.015	31	4.03
final wood	1.67	1.06	0.52	0.037	0.013	40	5.92
P. alba (Spain) (Demi)							
dark wood	1.02	0.82	0.56	0.033	0.013	33	4.72
light wood	1.32	0.91	0.56	0.035	0.010	34	4.95
P. hybrida * (Iran) (Demi)							
initial wood	1.581	1.173	0.595	0.052	0.033	33	5.25
final wood	2.009	1.457	0.930	0.045	0.025	44	7.6

* According to Bieb.

TABLE 17. – CHARACTERISTICS OF MEDULLARY RAYS *

Types	No. of rays per mm. in tangential direction	No. of cells forming height of rays			Average measurement of rays in mm.	
		max.	average	min.	height	width
P. alba (Piedmont plain)	8	18	12	7	0.264	0.014
P. alba 'Roumi' (Syria)	9	21	12	6	0.250	0.015
P. tremula (Piedmont plain)	9	23	14	5	0.363	0.018
P. tremula (Piedmont mountain)	10	29	12.6	4	0.322	0.021
P. hybrida ** (Iran)	7.7	31	15	7	0.405	0.020
P. nigra (Cyprus)	10.3	20	11	5	0.285	0.016
P. nigra 'Hamoui' (Syria)	8	18	13	6	0.308	0.014
P. nigra 'Farsi' (Syria)	10.7	21	13	5	0.295	0.019
P. nigra 'Blanquillo de Granada' (Spain)	11	25	12	6	0.290	0.015
P. nigra 'Spindar' (Iraq)	11.1	17	10.8	4	0.280	0.016
P. nigra 'Phräss' (Kashmir)	10	20	12.2	7	0.270	0.014
P. x *euramericana* cv. 'I-214'	9	29	14.9	8	0.358	0.014
(Switzerland)			30–3		0.1 – 0.7	
(Germany)			38–5		0.1 – 0.7	
P. x *euramericana* 'Chopa de Granada' (Spain)	8	28	15.6	3	0.349	0.013
'Negrito de Granada' (Spain)	8	22	15	7	0.363	0.014
'Pinseque de Zaragoza' (Spain)	12	24	13	6	0.270	0.016
P. euphratica						
(Syria)	12	25	16	6	0.374	0.020
(Iraq)	10	19	9.8	2	0.308	0.016
P. ciliata (Punjab)	9.6	25	16.9	7	0.350	0.019

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* All data, with the exception of those for Switzerland and Germany, were supplied by L. Demi of the Istituto del Legno, Florence.

** According to Bieb.

TABLE 18. – DENSITY OF POPLAR WOOD

Type	Author	Density air-dried	Density seasoned			Basic density
			min.	average	max.	kg/m³
P. nigra	Mayer Wegelin			0.41		390
P. tremula	”			0.45		390
P. alba	”			0.46		
P. balsamifera	”			0.36		
P. x *euramericana*	Jacquiot	(15 %)0.415-0.526				
P. nigra cv. ‘italica’	”	” 0.415				
P. x *canescens*	”	” 0.40				
P. tremula	”	” 0.53				
P. x *euramericana* cv. ‘robusta’	Campredon	(12 %)0.400-0.450				
P. cv. ‘serotina de Sélys’	Fouarge and Sacres	” 0.455				
P. cv. ‘Bleu d’Exaerde’	”	” 0.366				
P. x *euramericana* cv. ‘marilandica’	Bienfait	” 0.412 – 0.472				
P. x *euramericana* cv. ‘regenerata’	Klauditz and Stolley		0.34	—	0.39	
P. x *euramericana*	”			0.42		
P. x *euramericana* cv. ‘berolinensis’	”			0.35		
P. x *euramericana* cv. ‘robusta’	”		0.45	—	0.47	
P. x *euramericana* cv. ‘marilandica’	”		0.39	–	0.42	
P. x *euramericana* cv. ‘grandifolia’	Jayme		0.311	0.327	0.342	289
P. x *euramericana* cv. ‘regenerata grandis’	”			0.329		295
P. tremula (x *canescens*?)	”		0.298	0.329	0.369	297
P. x *berolinensis*	”		0.328	0.358	0.375	317
P. x *euramericana* cv. ‘gelrica’	”		0.355	0.382	0.406	333
P. x *euramericana* cv. ‘serotina’	”		0.363	0.392	0.412	344
P. x *euramericana* cv. ‘robusta’	”			0.447		376
P. trichocarpa	”		0.401	0.426	0.472	375
P. x *canescens*	”		0.411	0.488	0.627	421
P. x *euramericana* f. pl.	Lenz	0.84 (unseasoned)		0.415		

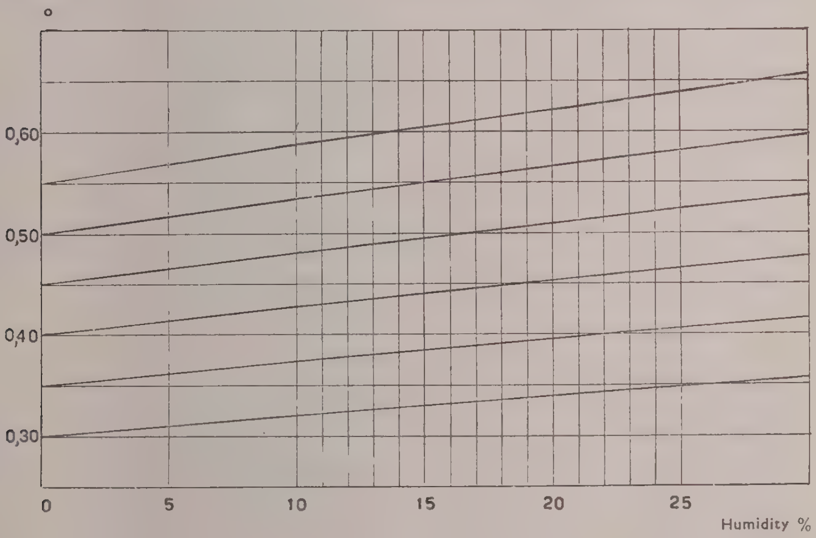
TABLE 18. – DENSITY OF POPLAR WOOD (*concluded*)

Type	Author	Density air-dried	Density seasoned			Basic density
			min.	average	max.	kg/m³
P. nigra	Kollmann	(15 %)0.45		0.41		
P. canadensis	”	” 0.47		0.43		
P. tremula	”	” 0.49		0.45		
P. deltoides	Brown, Panshin and Forsaith		0.37	—	0.43	320–370
P. tremuloides	”			0.40		360
P. deltoides	Committee of Paper Industries of U.S.A. and Canada			0.37		
P. tremuloides	”			0.35		
P. alba	Giordano	(15 %)0.44-0.54	0.40	—	0.48	
P. tremula	”	(12 %)0.57				
P. x *euramericana* cv. ‘I-214’	”	(12 %)0.332				
P. x *euramericana* cv. ‘I-37’	”	” 0.350				
P. x *euramericana* cv. ‘I-455’	”	” 0.319				
P. x *euramericana* cv. ‘I-476’	”	” 0.368				
P. x *euramericana* cv. ‘I-488’	”	” 0.386				
P. x *euramericana* cv. ‘I-154’	”	” 0.377				
P. x *euramericana* cv. ‘monilifera’	”	” 0.415				
P. x *euramericana* cv. ‘I-214’	Currò	0.66 (unseasoned) (15 %) 0.404 (*see* diagram)				
P. nigra cv. ‘Spindar’(Iraq)	Giordano	(12 %)0.49				
P. euphratica (Iraq)	”	” 0.46				
P. ciliata (Punjab)	”	” 0.36				
*P. hybrida** (Iran)	”	” 0.440 – 0.540				
P. x *euramericana* cv. ‘Chopa de Granada’	”	” 0.374				
cv. ‘Negrito de Granada’	”	” 0.365				
cv. ‘Pinseque de Zaragoza’	”	” 0.501-0.514				
P. nigra cv. ‘Bordils’	Llensa	” 0.508				
cv. ‘Poncella’	”	” 0.454				
P. x *euramericana* ‘Canada de Bordils’	”	” 0.424				

* According to Bieb.

tent. Although the figures for the density of green woods are not comparable among themselves and can only be used to determine the total moisture content, those for the density of oven-dried woods or air-dried woods (12 to 15 percent) are comparable for different species, clones or cultivars, and consequently can provide some very useful general information. One extremely important factor, however, particularly for the pulp industry, is the basic density; that is, the ratio between the weight of a test specimen when oven-dried and the volume at saturation point of the fibers. With this ratio the weight of the dried wood to be processed can be calculated direct from the volume (without bark) of a stand.

DIAGRAM 17. – VARIATION IN THE DENSITY OF POPLAR WOOD IN RELATION TO MOISTURE CONTENT (GIORDANO); P_0 REPRESENTS THE DENSITY (AIR-DRIED)



The data of several authors are summarized in Table 18.

Notwithstanding the variations of the figures in Table 18, it is clear that the wood of the fast-growing Euramerican hybrids is lighter than that of the typical *P. nigra*, while that of *P. tremula* and *P. alba* is appreciably heavier.

As regards the correlation between the density of the wood and the part of the tree from which it is taken, data from Germany (Mayer Wegelin) indicate that the density decreases from the butt up to the crown, whereas observations from Switzerland (Lenz) would seem to prove the contrary. While it may not be possible to provide a definitive answer, it is perhaps of greater importance to consider the variations in density, particularly in relation to successive growth rings. The diagrams for a fast-growing Euramerican hybrid ('I-214') will give a more accurate idea of the variation in density. Since the test specimens were taken on two perpendicular diameters, it might reasonably be supposed that a true average could be obtained, which cannot be obtained from isolated test specimens.

The diagrams and the observations of other research workers indicate that no grounds exist for believing that there is a wide variation between the density of dried sapwood and the more or less colored heartwood of the trunk, save for *P. alba*, which shows true duraminization.

The width of the growth rings does not have a definite bearing on density: the observations of the author of this chapter have proved the impossibility of finding a law of correlation for the Euramerican hybrids in the Po Valley. Data from Switzerland (Lenz) also appear to show that there is no marked relation between the factors mentioned.

To convert density at a certain moisture content to density at another level, use may be made of a table established on the basis of the coefficient of shrinkage = 0.30 ascribed to the species in question.

Relation between wood and moisture content

The distribution of moisture in the trunk of poplars provides a very interesting subject for study, because it does not conform to the general laws that have been determined for other broadleaved species. According to Swiss data, the part of the tree with the highest moisture content at the end of February is situated at a point between the center and the periphery of the sections. As regards height, it is greatest at the base of the trunk.

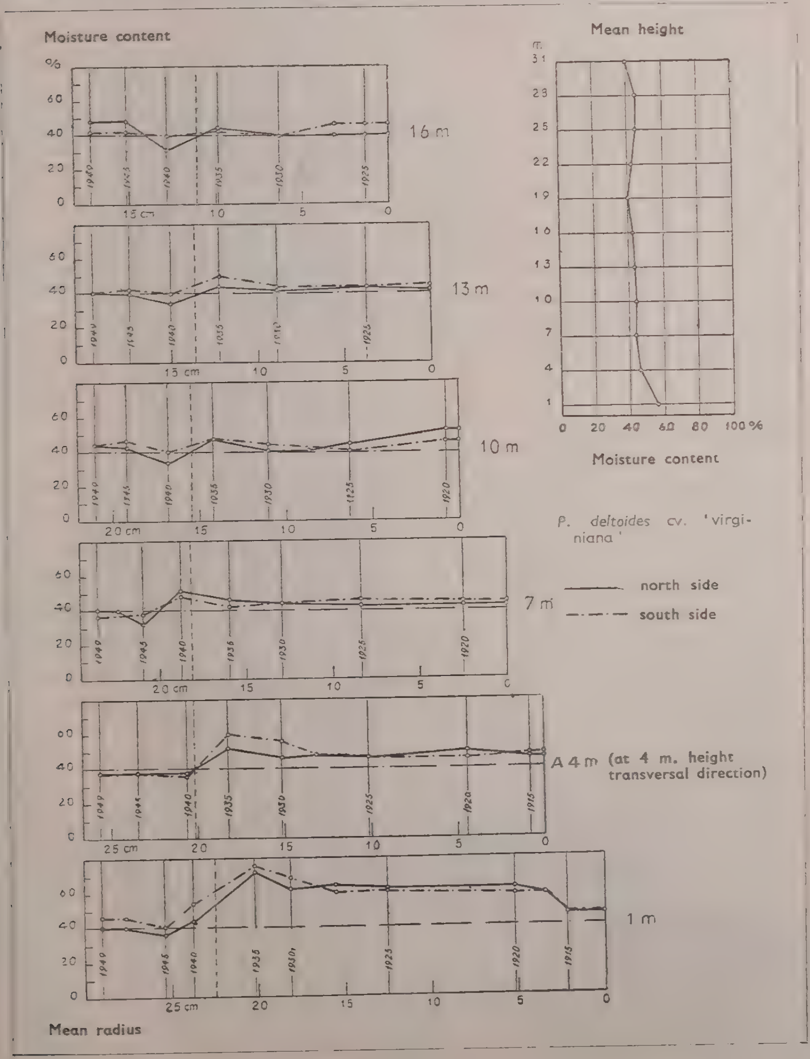
Lenz gives the moisture content of the unseasoned trunk as a percentage of the unseasoned volume, as shown in Diagram 18.

From tests performed on four specimens of *P.* x *euramericana* 'I-214' in the same stand felled at the beginning of March, June, September and December respectively, it can be affirmed that the highest moisture content is always to be found at the base of the tree toward the center of the sections. In March and December moisture content is lowest in the crown, while in June and September it is lowest at the mid-point of the tree. Diagram 19 shows these variations ring by ring, as well as the balanced averages, giving the figures for high moisture content at all seasons and at different heights in the trunk.

During seasoning, it takes some time for the free water to evaporate; when the water content falls below the saturation point of the fibers, the wood begins to shrink.

The saturation point of fibers for Euramerican hybrids cultivated in northern Italy (Giordano) varies between 30 and 40 percent and is generally 0.32.

DIAGRAM 18. – MOISTURE CONTENT OF THE UNSEASONED TRUNK AS A PERCENTAGE OF THE GREEN VOLUME – *P. deltoides* cv. 'virginiana' (LENZ)



According to Belgian data (Fouarge) the saturation point for cultivated hybrids varies between 33.75 and 39.98 percent; Bienfait (the Netherlands) found values between 26.9 and 30.5 percent for *P.* ' marilandica '.

Shrinkage figures supplied by various authors are summarized in Table 19.

The coefficient of volumetric shrinkage (for various *P.* x *euramericana* hybrids) according to Fouarge, varies between 0.32 and 0.44, while Giordano puts it at between 0.20 and 0.32, with the most frequent value at about 0.28.

Mechanical strength

Although rather light, poplar wood has a fairly satisfactory mechanical strength and deserves to be more highly valued than it is; but to give good results, it must be free of any deterioration. The data derived from tests made in several countries are summarized in Table 20.

No explicit law of correlation between the thickness of the growth rings and strength has been found; between density and strength, however, the law expressed in Diagram 21 has been established.

Diagram 20 shows the variation in axial compression strength in relation to moisture content.

Durability of poplar wood

Poplar wood is usually not considered to be durable, but if it is in a dry atmosphere, or completely submerged in water, it lasts fairly well, provided that it is free from attacks by fungi, insects or teredos. It is claimed that part of the piling foundations of houses in Venice are of *P. nigra* ' italica '. When old poplars are uprooted in the Poitiers marsh in France, the ends of the original sets, used to establish the stands, show no deterioration.

With alkalis, poplar wood is of moderate or slight durability; with acids its durability varies.

Other physical data

Coefficient of the thermal conductivity

P. nigra (moisture content 15 %) kcal/hr./m^2/°C./m. thick:
0.147-0.162 (Kollmann)

Calorific value

P. nigra kcal/kg. 4,129 (Kollmann)

DIAGRAM 19. – VARIATIONS IN MOISTURE CONTENT ACCORDING TO FELLING SEASON, HEIGHT AND ANNUAL RING IN A TRUNK OF *P.* x *euramericana* cv. 'I-214' (CURRÒ)

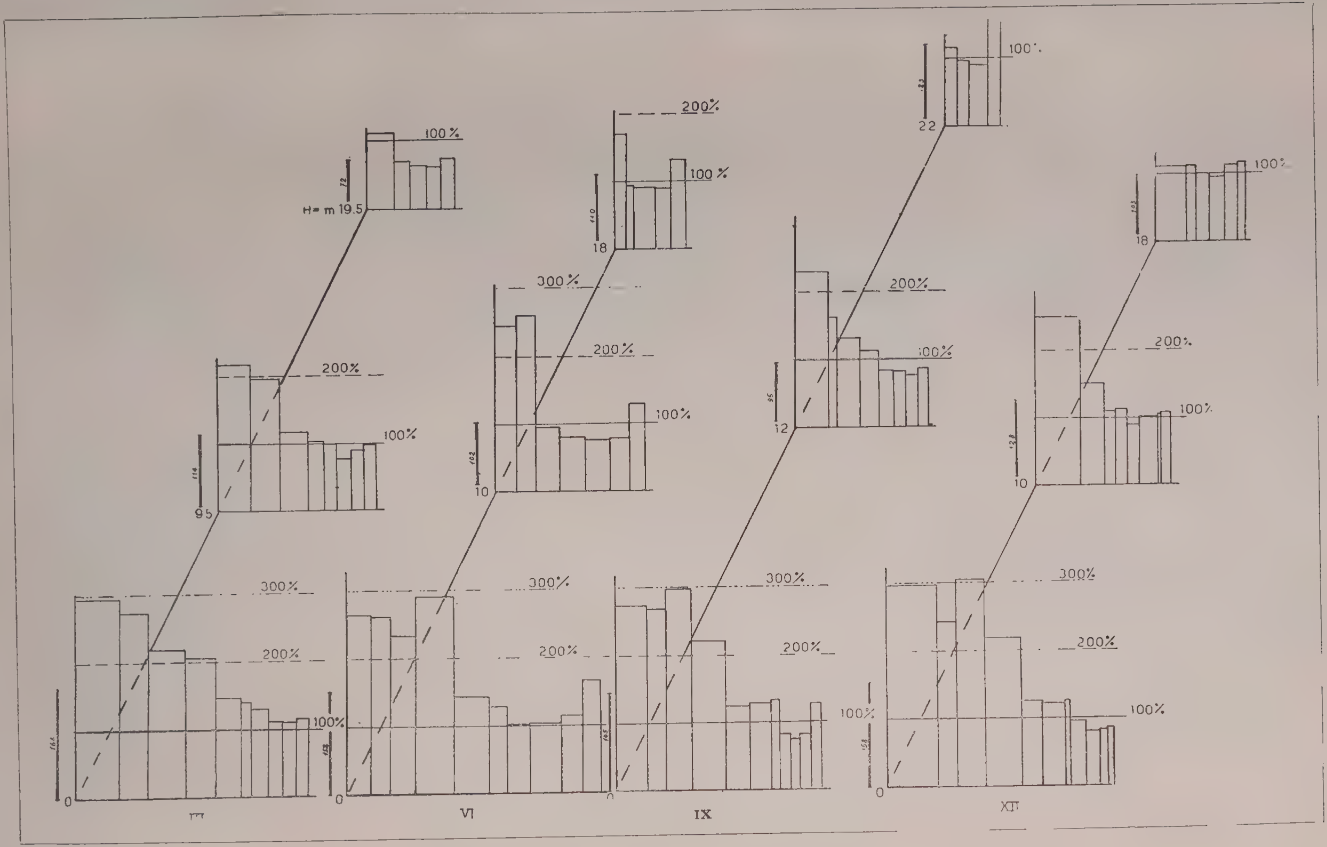
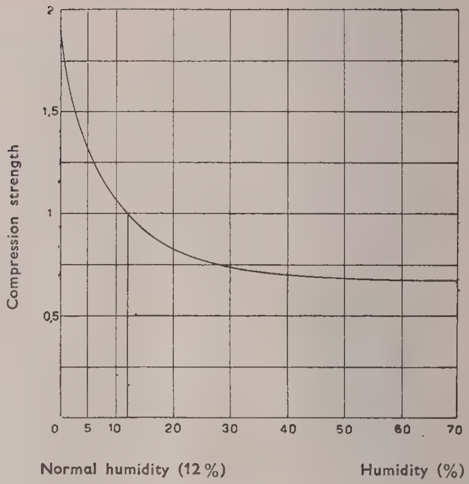


DIAGRAM 20. – CORRELATION BETWEEN AXIAL COMPRESSION STRENGTH AND MOISTURE CONTENT (%) FOR SEVERAL CULTIVATED *P.* x *euramericana* HYBRIDS.

(G. GIORDANO)



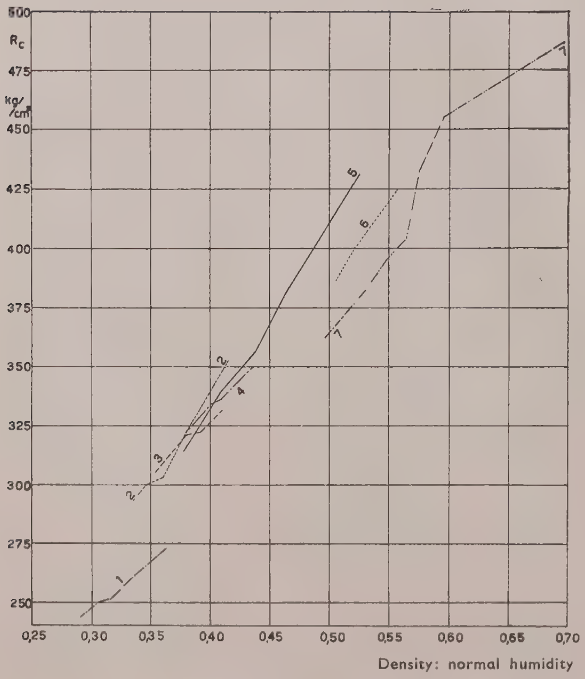


DIAGRAM. 21. – CORRELATION BETWEEN AXIAL COMPRESSION STRENGTH (Rc) AND DENSITY AT NORMAL MOISTURE CONTENT(12 %) FOR THE FOLLOWING SPECIES AND CLONES: (1) *P.* x *euramericana* cv. 'I-455'; (2) *P.* x *euramericana* cv. 'I-501'; (3) *P.* x *euramericana* cv. 'I-488;' (4) *P.* x *euramericana* cv. 'Carolin'; (5) *P.* x *euramericana* cv'?';(6) *P. tremula*, Alps origin; (7) *P. tremula*, Piedmont plain origin.

(G. GIORDANO)

TABLE 19. – SHRINKAGE OF POPLAR WOOD *

Type	Author	Shrinkage			Volumetric shrinkage
		longitudinal	radial	tangential	
		as percentage of figures for green wood			
P. deltoides	Committee of Paper Industries of U.S.A. and Canada				14.1
P. deltoides	Kollmann	0.6	3.9	9.2	13.7
P. tremuloides	”	0.5	3.5	6.7	10.7
P. nigra	”	0.3	5.2	8.3	13.8
P. x *euramericana,* various	Lenz				11.6 – 14.8
P. tremuloides	Committee of Paper Industries of U.S.A. and Canada				1.5
		as percentage of figures for dry wood			
P. tremula	French data				22.6
P. x *canescens*	”				14.7
P. nigra cv. ‘italica’	”				21.5
P. x *euramericana* cv. ‘marilandica’	Bienfait	0.4-0.7	2.7-3.9	8.2-10.1	15.1 – 24
P. x *euramericana*	French data				8.7 – 11.5
P. x *euramericana,* various	Vaccarone				12.3 – 16.1
sapwood					
heartwood					
P. x *euramericana,* various	”	0.2-0.4	1.9-2.3	7.5-10.6	
P. x *euramericana,* various	Giordano	0.2-0.3	2.0-4.5	5.1-7.5	8 – 11.2
P. x *euramericana* ‘robusta’	Campredon				13.8 – 19.5

* On the basis of data by different authors.

TABLE 20. – MECHANICAL STRENGTH OF POPLAR WOOD

Types	Author	Density g/cm^3	Moisture content %	Axial compression strength kg/cm^2	Bending strength kg/cm^2	Impact resistance	Modulus of elasticity kg/cm^2	Tensile strength kg/cm^2	Hardness (by the Janka test)
P. nigra	Kollmann	0.45	(15)12	350	650	0.34 kgm/cm^2	88 000	770	320
P. deltoides	”	0.47	(15)12	345	600	0.50 kgm/cm^2	96 000	—	320
P. x *euramericana* ‘ marilandica ’	Bienfait	0.45	12	338	—	—	50 980	—	—
id.	”	0.45	12	—	729	—	66 000	—	—
P. x *euramericana*	Fouarge	0.46	12	388	724	0.30 kgm/cm^2	—	—	—
P. x *euramericana*	”	0 37	12	252	605	0.48 ”	—	—	—
P. x *euramericana*	”	0.37	12	296	514	0.15 ”	—	—	—
P. x *euramericana* ‘ robusta ’	Campredon	0.40-0.45	12	341-483	690-1 120	1.06-3.44kgm.	65 961-160 781	—	—
P. x *euramericana*	Giordano								
‘ I-214 ’	”	0.33	12	265	570	1.10 ”	—	—	169
‘ I- 37 ’	”	0.35	12	277	596	0.87 ”	—	—	166
‘ I-455 ’	”	0.32	12	255	523	0.90 ”	—	—	170
‘ I-476 ’	”	0.37	12	312	633	1.00 ”	—	—	186
‘ I-488 ’	”	0.39	12	321	691	1.40 ”	—	—	224
‘ I-154 ’	”	0.38	12	302	650	1.70 ”	—	—	208
‘ I-monilifera ’	”	0.42	12	370	822	—	—	—	—
P. tremula	”	0.57	12	520	1 012	3.47 ”	—	—	332
P. nigra ‘ Spindar ’ (Iraq)	”	0.49	12	487	—	—	—	—	—
P. euphratica (Iraq)	”	0.46	12	405	—	—	—	—	—
P. tremula	Venet	0.511	15	364	770	—	—	—	—
P. deltoides ‘ Carolin ’	”	0.418	15	310	828	—	—	—	—
P. x *euramericana* ‘ regenerata ’	”	0.399	15	329	756	—	—	—	—

TABLE 21. – FIGURES OF RESISTANCE OF POPLAR WOOD [1]

Types	Author	Density g/cm^3	Moisture content %	Axial compression corrected for density[2]	Static bending corrected for density[2]	Ratio bending strength/axial compression	Flexibility index[3]	Dynamic bending index.[4]
P. tremula	Jacquiot	0.53	15	9.3	22.0	2.3	26.8	1.5
P. tremula	Giordano	0.57	12	9.2	18.8	2.04	28	—
P. x *canescens*	Jacquiot	0.40	15	7.8	18.0	2.3	31	1.0
P. nigra 'italica'	,,	0.42	15	9.5	20.2	2.1	30.0	1.7
P. x *euramericana* 'robusta'	,,	0.47	15	7.33	19.8	2.7	22.1	1.9
P. deltoides 'Carolin'	,,	0.48	15	8.01	18.5	2.4	30.1	1.7
P. deltoides 'virginiana'	,,	0.48	15	7.15	18.2	2.5	21.5	1.9
P. x *euramericana*	Fouarge	0.46	12	8.5	15.9	1.86	28.7	1.4
P. x *euramericana*	,,	0.37	12	6.9	16.6	2.40	20.5	3.6
P. x *euramericana*	,,	0.37	12	8.1	14.0	1.73	36.7	1.2
P. x *euramericana*	Giordano							
'I-214'	,,	0.33	12	8.0	17.1	2.03	24	—
'I- 37'	,,	0.35	12	8.0	17.2	2.15	24	—
'I-455'	,,	0.32	12	8.0	16.3	2.03	27	—
'I-476'	,,	0.37	12	8.5	17.2	2.03	27	—
'I-488'	,,	0.39	12	8.2	17.8	2.17	27	—
'I-154'	,,	0.38	12	8.0	17.2	2.15	24	—
'I-monilifera'	,,	0.42	12	8.9	19.7	2.22	33	—
P. nigra 'Spindar' (Iraq)	,,	0.49	12	9.94	—	—	—	—
P. euphratica (Iraq)	,,	0.46	12	8.80	—	—	—	—
P. tremula	,,	0.511	15	7.14	15.10	—	—	—
P. deltoides 'Carolin'	,,	0.418	15	7.41	19.80	—	—	—
P. x *euramericana* 'regenerata'	,,	0.78	15	8.25	18.80	—	—	—

---

[1] On the basis of preceding data and data of other experimenters. [2] $\frac{\text{strength (kg/cm}^2\text{)}}{100 \times \text{density (g/cm}^3\text{)}}$ [3] Ratio between span and deflection at rupture. [4] *Norme française* B 51-009.

Table 22. – Chemical composition of poplar wood (*continued*)

Species	Cross and Bevan cellulose %	Cellulose pentosans %	Cross and Bevan cellulose without pentosans %	Lignin %	Pentosans (total) %	Degree of solubility in:				Ash %
						alcohol / benzene %	water at 18° C. %	water 100° C. %	NaOH 1% %	
P. nigra: at top										
heartwood	66.1	21.9	51.6	23.7	22.2	2.28	1.21	1.78	15.9	1.09
sapwood	63.8	14.1	54.8	22.5	21.5	2.34	1.06	2.06	14.5	0.56
at mid-height:										
heartwood	65.4	19.9	52.4	23.4	21.1	1.90	1.25	1.78	14.3	0.92
sapwood	62.8	18.3	51.3	23.6	22.0	2.44	1.00	2.03	15.1	0.61
at base:										
heartwood	66.1	18.4	53.9	18.8	22.5	1.10	0.73	1.11	11.6	0.86
sapwood	68.7	19.4	55.4	20.4	22.1	1.53	0.82	1.23	13.3	0.83
(Boessneck, Brossa Viviani)										
P. alba: at top										
heartwood	60.7	23.5	46.4	18.9	24.4	2.85	1.37	2.10	17.1	0.58
at mid-height:										
heartwood	59.8	20.1	47.8	20.5	25.0	6.10	2.27	3.31	18.6	0.43
sapwood	67.3	19.8	53.9	19.2	24.1	2.85	1.59	2.46	16.8	0.53
at base:										
heartwood	63.5	18.9	51.5	18.6	25.8	6.17	1.54	2.71	18.7	0.41
sapwood	65.7	21.1	51.9	17.5	26.0	2.20	1.64	2.26	16.8	0.58
(Boessneck, Brossa Viviani)										

TABLE 22. - CHEMICAL COMPOSITION OF POPLAR WOOD (*continued*)

	Cellulose without pentosans %	Pentosans %	Hexoses %	Lignin %	Furfural %	Extracts in:			Proteins (N × 6.25) %	Ash %
						ether %	alcohol %	alcohol + benzene %		
P. tremula (Schwalbe and Becker)	47.11	24.47	—	18.24	12.64	1.08	2.08	2.87	0.63	0.32

	Cellulose without pentosans %	Cellulose pentosans %	Lignin %	Degree of solubility in:		Acetyl %	Ash %
				water %	acetone %		
P. 'regenerata' (Klauditz and Stolley)	44.6	15.9	24.3	5.1	1.6	4.1	0.99
P. 'regenerata'	49.0	15.2	26.6	1.6	1.7	3.1	0.73
P. x *euramericana* 'Grafhorst'	48.2	15.1	22.5	4.0	1.3	4.3	0.66
P. x *berolinensis*	48.7	15.4	22.5	3.7	1.5	3.5	0.60
P. 'robusta'	50.9	16.6	20.6	2.0	1.1	3.6	0.49
P. 'marilandica'	47.7	16.0	22.7	4.4	1.3	3.3	0.96
P. 'marilandica'	46.7	15.7	23.9	2.2	1.3	4.4	0.84

Table 22. – Chemical composition of poplar wood (*concluded*)

	Cellulose %	Lignin %	Degree of solubility in:	
			water %	ether %
P. tremuloides	65.5	23.4	3.0	1.1
P. deltoides (Committee of the Paper Industry of the U.S.A. and Canada)	63.2	23.6	2.0	0.4

Table 23. – Variations in the chemical composition of wood in a 10-year-old trunk (Jayme)

P. x *euramericana* cv. ‘ serotina ’				
Distance from the ground at which sample was taken	m.	1–2	3–4	5–6
Number of annual growth rings according to height (average)		10	6	5
Wood analysis				
Ash	%	0.52	0.52	0.48
Methyl alcohol/benzene extract	%	2.32	3.08	3.39
Lignin, based on extractive-free wood	%	20.35	22.75	22.73
Pentosans (hypothetical, furfural x 1.375)	%	20.32	17.03	19.40
Pulp yield (sulphate) (155°C.)	%	55.69	53.29	51.38
Cellulose analysis				
Ash	%	1.26	1.12	—
Methyl alcohol/benzene extract	%	1.10	1.48	1.28
Lignin	%	2.19	3.47	4.12
Pentosans (hypothetical, furfural x 1.375)	%	19.25	17.78	17.82
Alpha cellulose	%	79.96	82.01	81.84

Speed of sound transmission along the fibers

P. alba (density 0.54): 5,750 m/s
(density 0.50): 6,000 m/s

P. x *euramericana* 'I-455'

Initial wood (density 0.31): 4,750 m/s
Final wood (density 0.40): 5,500 m/s (Barducci)

Coefficient of expansion through the effect of heat

P. deltoides

Tangential direction 32.6×10^{-6}
Radial direction 23.3×10^{-6} (Stamm)

D. CHEMICAL COMPOSITION OF POPLAR WOOD

Data supplied by different authors are by no means homogeneous, and they must therefore be considered separately.

a) Elementary composition

The figures for the elementary composition of poplar wood expressed in percentages are as follows:

	C	H	N
Populus tremula (trunk) according to Lange	50.31%	6.32%	0.98%
Populus tremula (shoots) according to Lange	51.02%	6.28%	1.05%

b) Chemical composition

Figures are given in the attached tables for the chemical breakdown of wood into its most common constituents. It is nevertheless useful to recall here that poplar wood (like that of other broadleaved species) has a higher gum and wax content than conifers which, on the other hand, contain more resins and terpenes.

c) Composition of ash of poplar wood

The composition according to *Holz als Roh- und Werkstoff* is as follows:

K_20 49.24%; Na_20_3 1.63%; CaO 23.73%; MgO 13.67%; Fe_2O_3 1.07%; P_2O_5 4.07%; SO_3 3.13%; SO_2 1.97%; Mn_2O_3 1.41%.

II. DEFECTS OF POPLAR WOOD

A. Defects of habit

Stems of poplar do not always have the theoretical form of a paraboloid of revolution but sometimes certain characteristics differ, and like any other divergence from the normal, they are defects.

Shoulders or buttresses at the base

Theories as to the origin of shoulders differ fairly widely. Some authors would say they are of mechanical origin; that is to say, that the tree develops anchorages to withstand bending by the force of the wind. Others, on the contrary, consider this an adaptation of the base of the tree to allow easier ascent of the sap, required for rapid growth, than the normal circumference would permit.

Unfortunately, neither theory explains why such buttressing occurs only in some species and not in others. In fact, the most pronounced shoulders are to be found in *P. nigra* cv. ' italica ' which, because of its very fastigiate habit, has its center of gravity nearer the ground than any other poplar and is consequently less affected by the wind. Further, it does not grow as rapidly as other types, and Euramerican hybrids in particular almost never have this defect.

It is therefore feasible that basal buttresses may be primarily a hereditary character, sometimes emphasized by environmental conditions (for example, by a marshy soil or very sloping ground).

The presence of buttresses is a drawback because they entail additional work in felling the trees, because they turn the fibers toward the base and create a diverse system of tissues that are likely to split and, lastly, because they are frequently associated with tension wood.

Asymmetrical transverse sections and excentric pith

Prolonged impact by specific mechanical force, for instance, a tree which is continually bent in one direction by the wind, easily creates conditions for an abnormal growth of a section of the bole in a certain direction. Foresters have known for a long time the deformation or ovalization of trunks of trees planted singly in the bottoms of valleys, where the prevailing winds blow in the direction of the axis of the valley, although for poplars, and especially the fast-growing, cultivated types, there are frequently other cases of ovalization. In fact, this defect may occur in trees on the edges of dense stands, where the crowns of trees at the interior

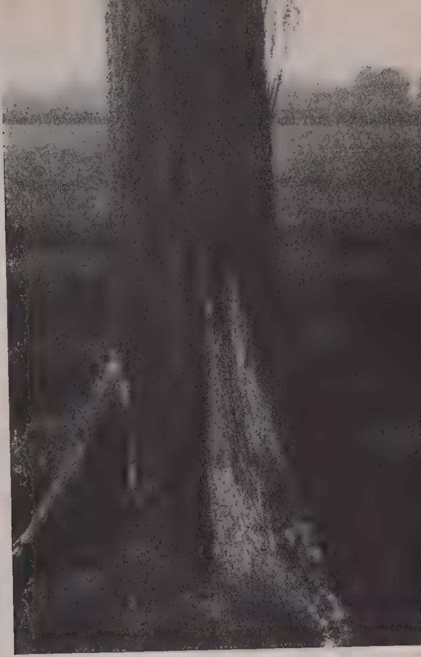


Figure 218. – Buttressing at the base of *P. nigra* cv. ' italica '.

Courtesy *G. Giordano*

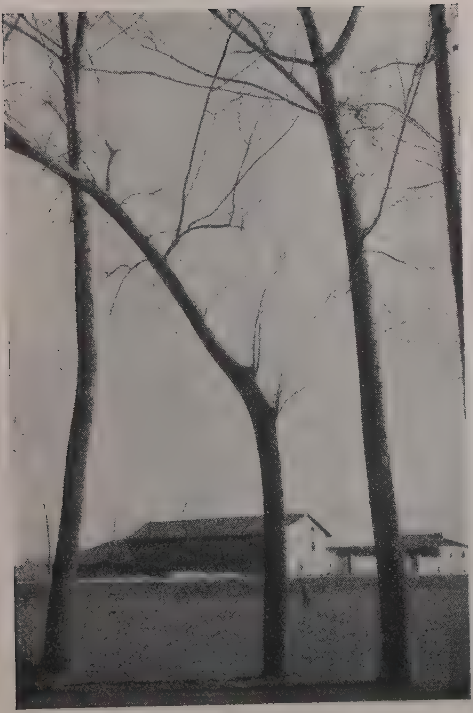


Figure 219. – A curved dominated poplar.

Courtesy *G. Giordano*

cause the individual trees on the edge to bend outward. The deformation that is sometimes seen in trees planted in rows running east-west, which show a tendency to develop their diameters toward the south, is more complex and difficult to explain, as is the case of trees near water which develop their diameters toward the water. In this case it is probably the result of the better growth of the corresponding part of the crown, which is often more spreading and has denser foliage on the southern side and toward the water.

Sometimes an oval or elliptical section is accompanied by excentric pith, and more often still contains tension wood. This is easily explained, as the same external influence (off-center stress on the basal section) may cause both defects.

Elliptical trunks, even those without tension wood, often have heterogeneous wood which greatly lowers their value. They have even another serious disadvantage for plywood, as there is appreciable loss of wood when the billet is veneer-peeled.

Another irregularity in transverse section which occurs fairly frequently in the quickly grown Euramerican hybrids but which is lacking in white poplars, the aspens and Near East types, is the undulation of the growth rings. An explanation may be sought in the quadrangular section of the young shoots of affected clones. The practical drawback of such an anomaly is negligible but when trees are being measured, this peculiarity must be taken into account.

Curved boles

If a poplar is particularly sensitive to light, a dominant canopy of the presence of higher crowns near together may cause irregular growth of the tree. Some types are particularly sensitive to phototropism, for example *P.* x *euramericana* ' serotina ' or ' regenerata ', ' I-214 ', etc., whereas others are only slightly sensitive or not at all, as for example *P. nigra* ' Hamoui ' and ' italica ' or *P.* x *euramericana* ' robusta '.

Poplar boles may also be curved mechanically in another way, that is, in a violent storm by a very strong wind. While wind can break or uproot most trees, with some hybrids with a rapid growth rate — especially in the spring when the sap is rising — it causes a permanent curvature of the stem, which may continue to increase while the shape of the crown is modified.

Any deviation of the tree from the vertical, which causes a curvature of the bole initiates the formation of tension wood and makes the timber of affected trees worthless.

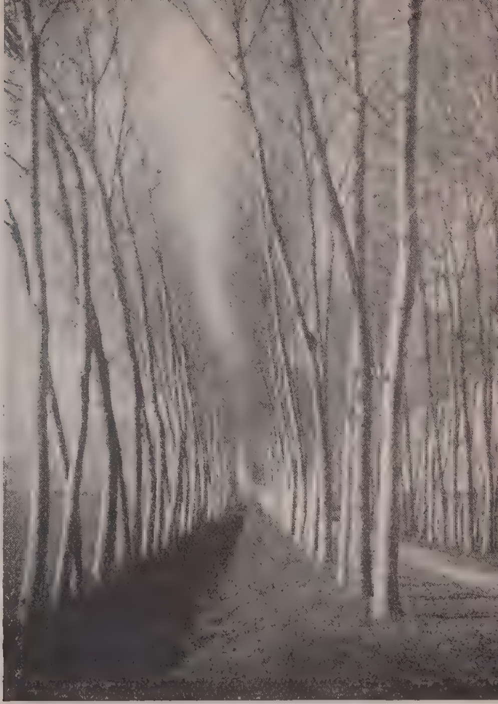
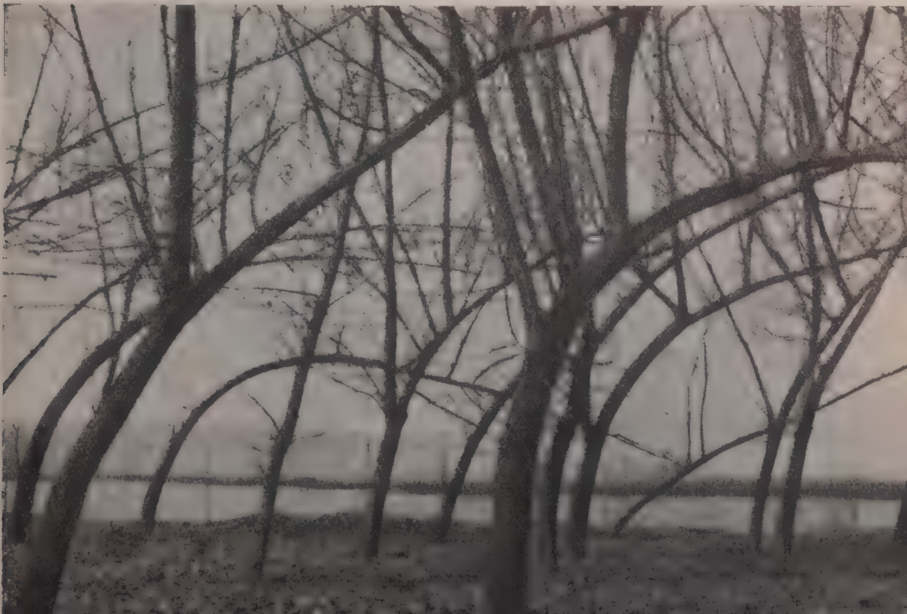


FIGURE 220. – Rows of poplar showing a general tendency to curvature on the open side and the bending of alternate trees where overcrowded.

Courtesy *G. Giordano*

FIGURE 221. – A 10-year-old poplar stand bent by the wind from the age of 5 years.

Courtesy *G. Giordano*



Injuries

Poplars grown with farm crops are frequently injured by animals and machines such as plows, harvesters, etc. Usually, however, they leave slight injuries on the bark which are soon healed over by the occlusion of the tissues, although permanent trace of the lesion will remain at the interior in the form of dry or marred wood. With deeper or repeated injuries, a reaction of the adjoining tissues is likely to take place and can result sometimes in voluminous growth, inside which the fibers deviate from their normal direction and become closely entwined.

With regard to bark injuries, it may be recalled that the removal of a strip of bark around the tree (girdling) does not always kill poplars, at all events not rapidly.

Frost cracks

This particular type of injury is unfortunately rather frequent in west and central Europe. It constitutes a serious defect, making the billets useless for veneer peeling and causing heavy losses in sawlogs.

In spite of the frequency and serious nature of frost cracks, it has not yet been possible to determine the temperature at which the danger begins, the other factors which may favor the action of low temperatures, nor the actual mechanism which causes the trunk to crack.

It should, however, be noted that:

a) owing to the low thermal conductivity of wood, with trees with a diameter of at least 10 to 12 centimeters, it takes rather a long time before the temperature outside and inside the trunk reaches equilibrium;

b) the coefficient of contraction (*see* page 423) is not the same in the two directions but is greater in the tangential direction.

Thus there is no doubt that with rapid cooling of the air, the layers of wood next to the bark are colder than those at the interior of the trunk. These outer layers are therefore under pressure, which has a tendency to make them contract. The core, however, is unaffected, or less affected, because it is not as cold and, in any case, it contracts less, having a different coefficient of contraction. Consequently, the higher tangential tension at the surface may cause cracking.

Other factors, however, must be taken into consideration. When the cold winter winds blow mainly in one direction, frost cracks occur on the windward side, while near watercourses they are usually on the side of the running water. In both cases the effect of a drop in temperature around the tree may be noted.

As a rule, frost cracks occur only on the lower part of the tree, less than 4 to 5 meters from the ground, without reaching the root flare. The reasons for such a phenomenon may be sought either in a hypothetical gradient of temperature at different levels from the ground (this would give an absolute minimum at between 1 and 3 meters), or by the fact that, as the diameter is greatest near the base, there may be considerable differences in temperature between the inside and the outside of the trunk. Near the crown, however, such differences are less marked and, at the collar, the ground and the root flares completely modify the effect of the low air temperature.

When frost cracking has occurred during the winter, the occlusion of the cambium tends to close the two edges of the wound in the spring and a small excrescence forms.

If, during the relatively short economic rotation of the poplar very low temperatures do not recur there is no reason for the frost crack to reopen, and after three or four years the scar may be barely visible. If, in subsequent winters, however, there is a severe drop in temperature, then each time the wound will reopen, being the weakest point. In the spring, the cambium tends to close the lesion and the excrescence increases

FIGURE 222. – This poplar was still growing vigorously two years after the bark had been completely stripped from its base.

Courtesy *G. Giordano*

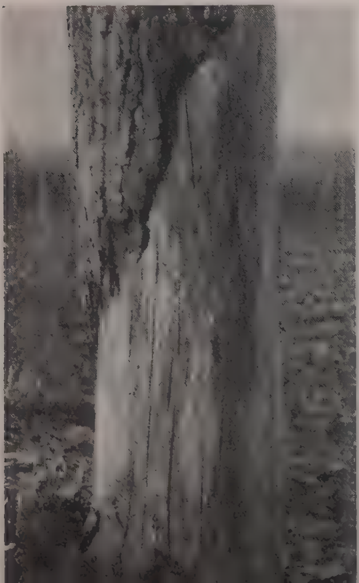
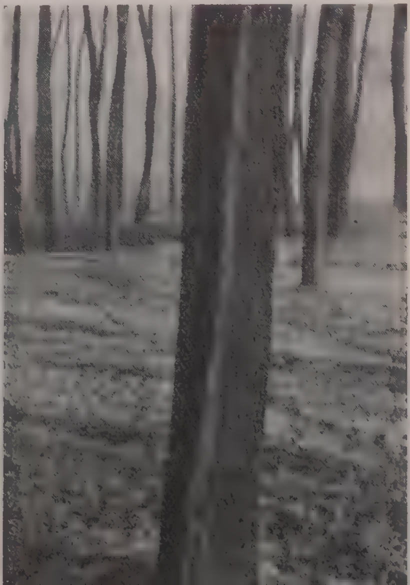


FIGURE 223. – A Euramerican hybrid, showing a frost crack.

Courtesy *G. Giordano*



in thickness to form a clearly raised ridge on the bark. It occasionally happens, although rarely, that two frost cracks appear; in this case they are never at the same level nor do they start at the same time.

Injury of a mechanical-technical nature to the butts, due to frost cracks, is aggravated by the fact that the spores of destructive fungi can easily penetrate the exposed tissue. Thus, very often, the wood all round a frost crack is completely marred, a condition which is sometimes identifiable by the exudation of blackish liquid.

Pollarding or topping

Trees are treated in this manner if the forester wishes to obtain from the poplars products other than workable timber; for instance, branches for fuel, smaller shoots for faggots, and leaves for litter or even forage.

Pollarding may be justified from an economic point of view if the area is short of fuel, but it has always a serious disadvantage in that pollards provide an ideal breeding ground for all xylophagous insects and the various types of tree parasites.

Topping, by cutting off a good part of the crown, greatly diminishes the woody increment of the tree and also causes the formation of excrescences which spoil the logs, so that they can never be used for veneers nor, very often, for sawing.

B. DEFECTS IN THE ANATOMICAL STRUCTURE OF THE TISSUES

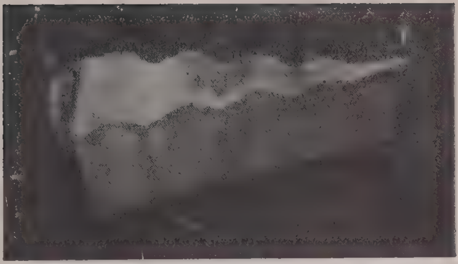
Twisted fibers

While mere twisting of the fibers does not appear to be as frequent in poplar as in other species, interlocked grain in successive growth rings is fairly common. Detailed studies have not yet been made of this anomaly, which the author of this chapter believes to be connected with rapid growth (as in the case of eucalypts), or considers a hereditary character. An attempt should be made to propagate selected stock to eliminate this defect, which unfortunately can only be detected in the felled tree or the stool.

Interlocked grain spoils mainly the technical properties of the timber; that is, areas of opposite grain appear during sawing, whereas in veneer peeling the sheet is heterogeneous. Lastly, logs with interlocked grain cannot be split.

FIGURE 224. – Poplar wood showing interlocked fibers.

Courtesy *G. Giordano*



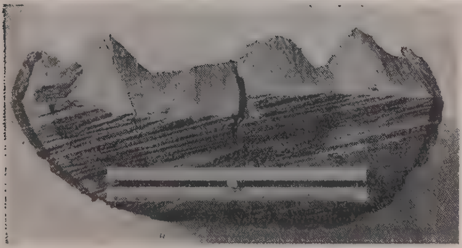
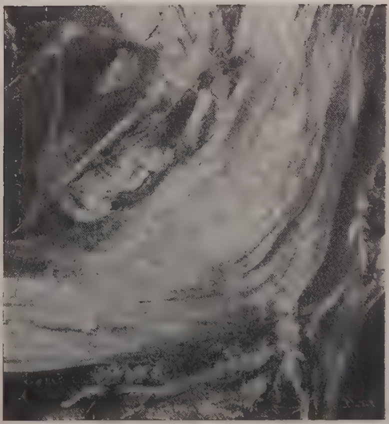


FIGURE 225. – A further example of interlocked fibers in poplar wood.

Courtesy *G. Giordano*

FIGURE 226. – Base of a poplar with wavy fibers.

Courtesy *G. Giordano*



Intertwined and tangled fibers

Cicatrization following injury, the shock stimuli that the tissues receive, localized or other compressions, or bud removal, may turn tissue cells from their normal position and cause intertwining and tangling of the wood fibers. In most cases this is a defect, because the logs cannot be veneer-peeled and the sawn timber is poor, heterogeneous in structure and difficult to plane. When, however, the combined abnormal tissues develop into a burl of figured wood (fairly frequent in *P. nigra*) the timber is highly valued by the furniture and marquetry industry (Figure 256).

At the foot of trunks having spurs, and especially in *P. nigra*, the tissues frequently show undulated folds which in section give a pleasant pattern; this is wavy grained wood. However, such material is very seldom used for decorative purposes. The same characteristic has been observed in France on gray poplars.

Cupshake

As has been seen, the anatomical and physical differences between summer and spring wood are comparatively slight: as poplar wood is fairly homogeneous, cupshake is not often found. In the Netherlands, however, some cupshake damage occurs and, in Morocco, *P. euphratica* is considered somewhat liable to this defect.

Knots

The mark left by branches on the bole of a tree cannot be stopped but much can be done to reduce to the minimum the defect caused by their presence. Every branch of a tree means a knot which may be adherent and lightly colored if the branch is still living, or loose and dark in color (this may vary with the clone and state of deterioration) if the branch is dead. Lastly, if the branches rot, they leave gaping cavities — a frequent occurrence in *P. alba.*

Usually the branches, and consequently the knots, are in whorls but between them there may be isolated branches; in this case it will be difficult to obtain choice logs. The seriousness of knots depends on the size of the branches and on their angle of insertion: fastigiate branches like those of *P.* x *euramericana* cv. ‘ robusta ’ and *P. nigra* cv. ‘ italica ’ produce oblique knots which cover a greater length of the bole than knots left by horizontal branches.

The lower branches can be pruned as soon as they are no longer necessary for the life of the tree (*see* the chapter on poplar cultivation). The

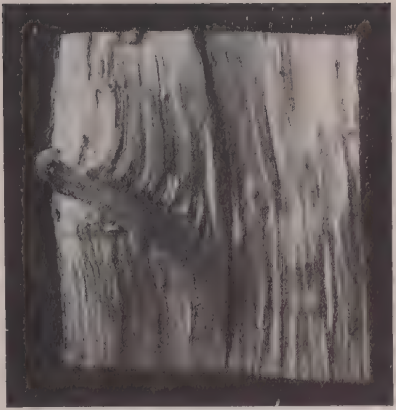


Figure 227. – A knot in poplar wood.

Courtesy *G. Giordano*

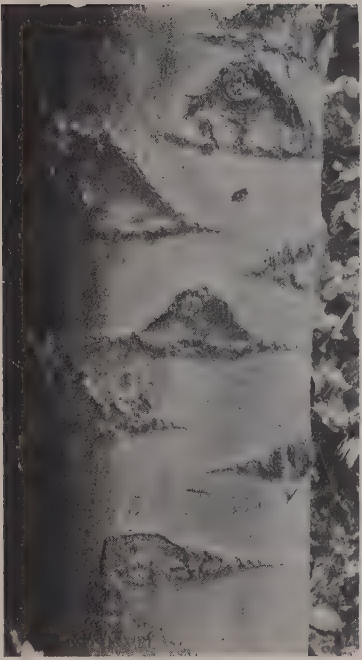


Figure 228. – Scars on the bark, indicating the presence of knots at the interior of the trunk.

Courtesy *G. Giordano*

knots, therefore, will be smaller and more important, will not rot, because the growth of the trunk will cover them before they are attacked by fungi. The aim of pruning should be to obtain a crown in equilibrium with the base in order to prevent the formation of tension wood. Climbing irons should never be used when pruning, on account of the damage they cause to the wood.

Fiber lesions due to wind

It has already been said that wind can bend poplars under certain conditions. In some cases, such bending may merely cause the fibers to stretch on the strained side and be compressed on the other but in other cases it may lead to a localized rupture of the fibers, which will show as a break in the continuity of the tissues throughout the transverse section. At the level of the rupture area, the cambium covers the wound and leaves a ridge which betrays the damage, even in the standing tree, to the expert.

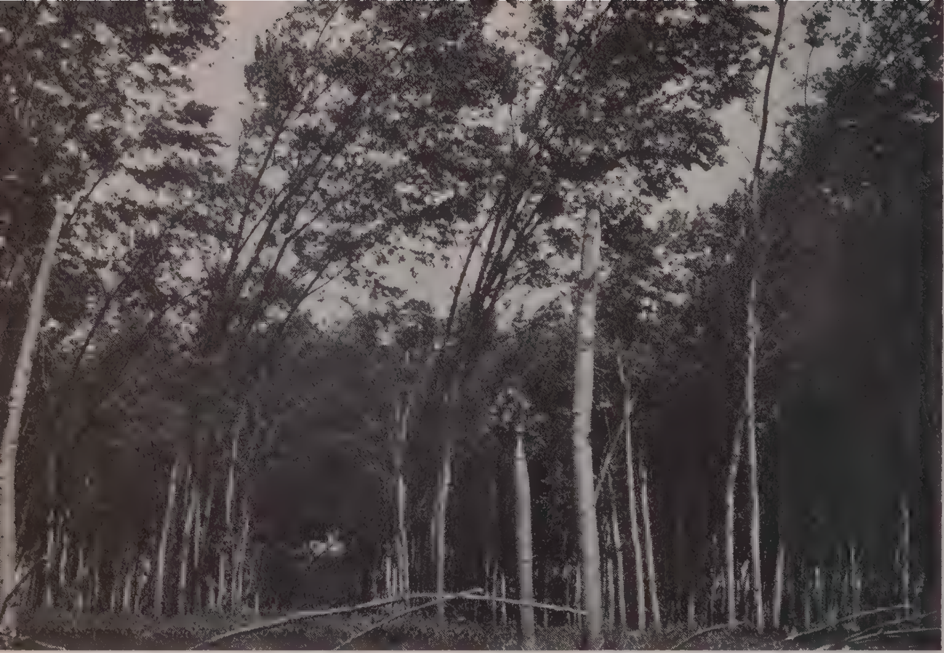


FIGURE 229. – A poplar stand damaged by wind. The trees which have not been snapped probably all have lesions of the fibers.

Courtesy *G. Giordano*

FIGURE 230. – A swelling on the outside of a poplar stem, indicating lesion of the fibers within.

Courtesy *G. Giordano*

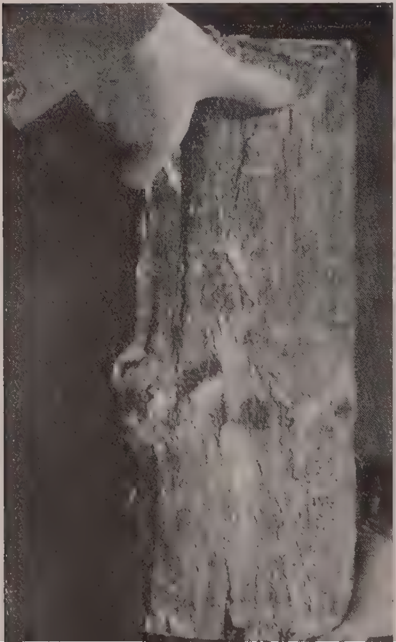
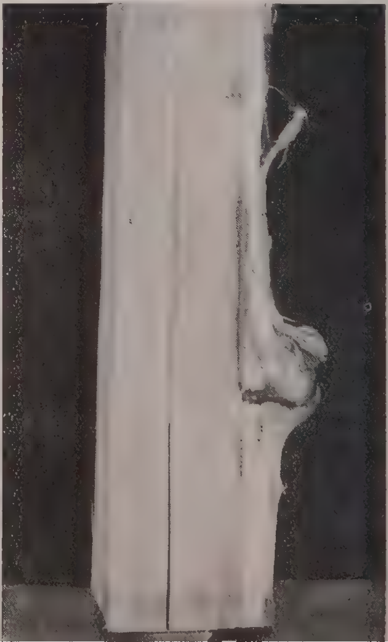


FIGURE 231. – Interior of the same stem.

Courtesy *G. Giordano*



When the tree is felled, the trunk very often breaks at these lesions, especially if the bark has also been injured and wood-destroying fungi have already started to attack at this point. Sometimes, however, the lesions are barely visible to the naked eye — an obvious danger if the trunks are cut into planks for scaffolding or for any kind of construction work. It is therefore advisable, when felling poplar stands that have been subjected to gales, to examine the trunks closely before converting them or, better still, to allocate them for uses where continuity of the fibers is unnecessary.

Tension wood

"Tension wood" is abnormal in that the fibers, instead of having a single, evenly lignified wall, have a wall divided into two layers, the outer lignified, the inner not. When this inner layer is treated with dyes or merely the appropriate chemical solutions, it swells considerably and consequently forms folds and curves which sometimes occupy a large part of the cell cavity. On swelling, the inner layer acquires a gelatinous appearance which has earned the fibers so affected the name of "gelatinous wood fibers" in England. Specific reagents show up the difference

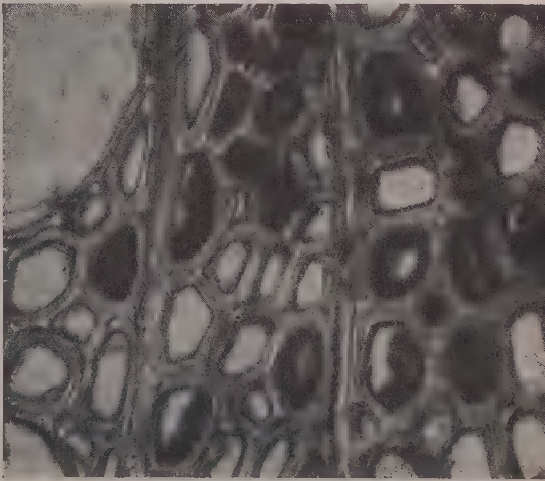


FIGURE 232. – Poplar wood with gelatinous fibers scattered in the tissue (x 400).

Courtesy *G. Giordano*

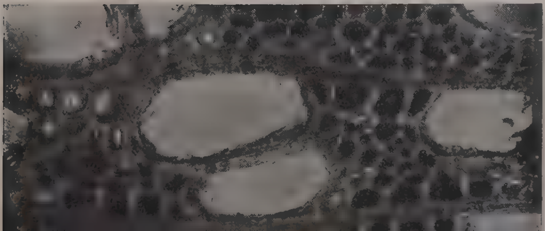


FIGURE 233. – A typical example of tension wood in poplars: nearly all the cell walls have a double layer (x 210)

Courtesy *G. Giordano*

in the chemical composition of the two layers. The reagent used in Germany and Italy is zinc chloroiodide, which turns the inner, gelatinous, non-lignified layer a violet blue while the other layer takes on the color of the reagent. In Switzerland, according to Delafield, hematoxylin is used, which colors the inner cellulose layer a light blue and the lignified layer a dark purplish blue. In Great Britain, fast green and gossypimine (cotton red) are used, which color the non-lignified walls green and the lignified ones red.

Chemical analysis confirms the dye tests. It is obvious that the composition of a normal fiber cannot be compared with that of a tension fiber; all that can be done is to compare the composition of a zone of normal wood with one where tension fibers occur.

Distinct differences can be seen from the analyses available:

Wood of *P.* x *euramericana* ' I-214 ' analyzed at the Torviscosa S.A.I.C.I. (1950)	Normal wood %	Tension wood %
Water extract	2.6	3.0
Alcohol/benzene extract	1.2	1.6
Loss by hydrolysis with 2 % HCl	34.1	27.9
Cross and Bevan cellulose from wood placed under water and alcohol/benzene extract containing pentosans	50.8	59.0 (+ 23.6 more than normal wood)
True cellulose (percent of raw material)	42.3	51.5 (+ 21.7)
Lignin (after extraction with water and alcohol/benzene, and hydrolysis, as percent of raw material)	18.2	14.7 (– 19.2)

Similar results were obtained at the laboratory of the Cartiere Burgo, Turin (1950) where in a single billet of *P. deltoides* cv. ' carolinensis ', normal wood was found to have a 27 percent lignin content and tension wood as little as 21 percent lignin content (i.e., 28.6 percent less than normal wood).

An analysis by Jayme of an 8-year-old poplar branch, carried out in 1954, gave the following results:

Components	Normal wood %	Tension wood %
Lignin	23.21	21.57 (7.07 less than normal wood)
Total pentosans (hypothetical)	16.09	12.81
Raw cellulose	51.64	60.92 (17.97 more than normal wood)
Soluble hemicellulose	35.57	29.20
True cellulose	40.89	49.16 (20.22 more than normal wood)

Lastly, an analysis by Jayme of sulphate pulp from *P.* x *euramericana* cv. 'robusta' gives the following:

Components and characteristics	Normal wood	Tension wood
Lignin	3.11 %	1.57 %
Degree of brightness	22	41
α cellulose content	74.91 %	88.81 % (18.6 more than normal wood)
Breaking length	8,620 m.	5,549 m.
Folding endurance	2,450	46

From the macroscopic point of view, the anomaly depends chiefly on the relative number of abnormal cells. In some cases they are scattered in a tissue of regular fibers and cannot be detected by the naked eye. In other cases, a whole zone of wood is affected and appears in transverse section as a snow-white patch generally standing out clearly from the yellowish color of the surrounding normal wood. Further, since the tension cells do not cut as easily as the others, cutting tools leave a cottony, furred surface, and tension wood has therefore come to be known as "furred" or "hempen" wood. Lastly, in longitudinal sections of sea-

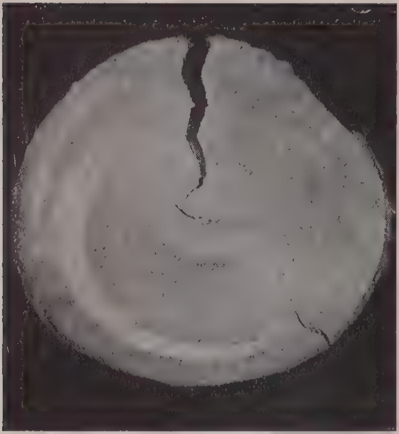


FIGURE 234. - Characteristic appearance of tension wood in a transverse section (note also interlocked fibers).

Courtesy *G. Giordano*

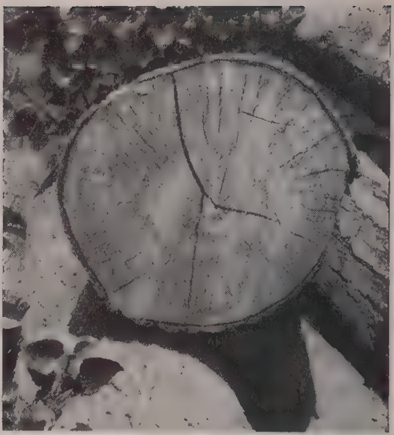


FIGURE 235. – A billet with a patch of tension wood: note the shrinkage cracks which are deeper than in the normal wood.

Courtesy *G. Giordano*

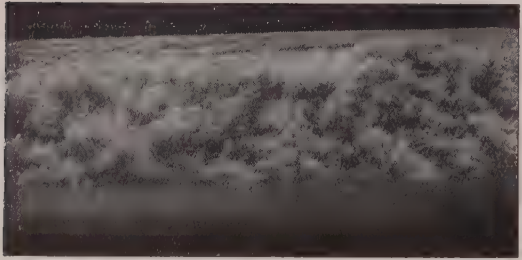


FIGURE 236. – Cottony surface obtained by sawing a billet of *P.* x *euramericana* containing abundant tension wood.

Courtesy *G. Giordano*

sonal wood the cottony surface is frequently sunken below the level of the surrounding normal wood. Some timber merchants affirm that even when a tree is still standing they can ascertain whether or not the butt log contains tension wood, from the peculiar sound this wood makes when struck by a hammer. This test can, however, only be used when tension wood occurs in the area immediately under the bark.

To ascertain if there is any tension wood in logs, the ends of the logs are painted with zinc chloroiodide or even with phloroglucin, which colors the lignified tissues a bright red and the tension wood a lighter color. Some authors, however, do not think that this system is always reliable.

Information on the distribution of tension wood in transverse section varies: sometimes it is said to lie on the longest radius of the transverse surface, and sometimes on the opposite side or in the intermediate areas. This defect can be seen in rapidly grown hybrids in the Po Valley even when the section is perfectly circular and with a true center. Further, tension wood sometimes shifts its position in different years. Therefore, the location of tension wood cannot be determined merely by examining the transverse section. If, however, the forces (gravity or wind) to which the tree is subjected are studied, valid hypotheses may be formulated, because abnormal wood is always on the side of the tree which is strained. Obviously, there are cases where the external force has been exerted for only a short time and the traces left are in the form of tension cells scattered through the normal fibers. The point to be emphasized is that the section never consists wholly of abnormal wood. This indicates that the forces which cause the formation of tension wood must be asymmetrical (thus excluding overpruning as a factor, as this would affect the whole section). With regard to distribution in the upper part of the tree, opinions still differ. In Italy, in poplars of a certain size (over 25 cm. in diameter) such as those used for sawing or for veneer peeling, the percentage of tension wood is always found to diminish from the base to the top,

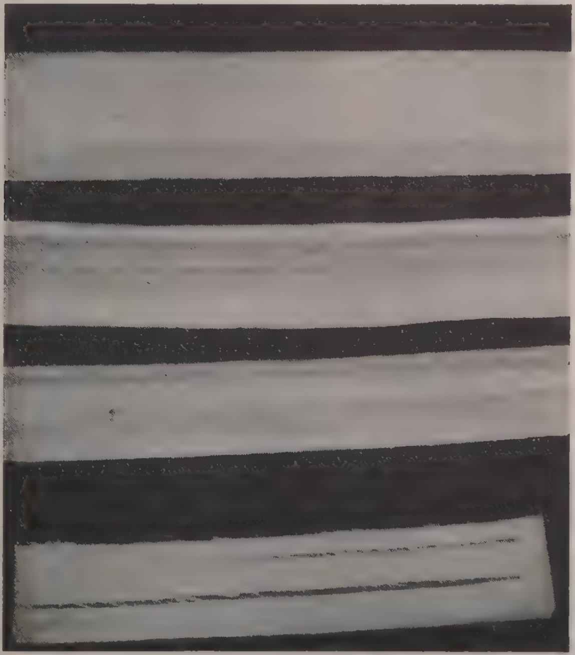


FIGURE 237. – Slats cut from the same poplar billet: (1) in an area of normal wood; (2) and (3) in an area of tension wood showing distortion of their shape; (4) *ibid.* in an area of tension wood showing collapse cracks.

supporting the hypothesis of mechanical origin. In France, however, tension wood, also called "taut wood," is very frequently found above the whorls of knots, though in some cases it may extend to the whole of the internodes.

The physical characteristics of tension wood differ appreciably from those of normal wood; it is much denser. Differences ranging from 10 to 31 percent higher can be detected in the same growth ring in oven-dried wood.

Shrinkage is greater in all three anatomical directions and consequently also in volume. Swiss data (1954), which refer to the green wood volume, give a greater average volumetric shrinkage of between 1.9 and 5.2 percent.

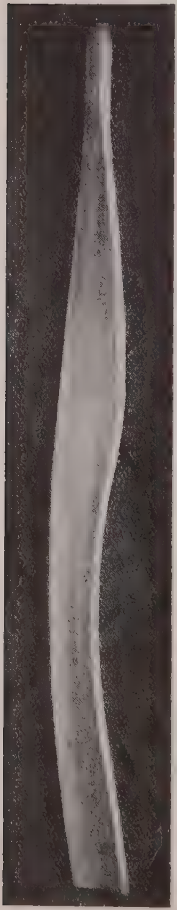
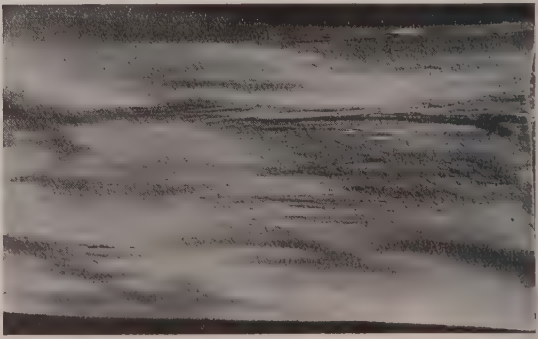


FIGURE 238. – A small plank cut from an area of tension wood, after seasoning.

Courtesy *G. Giordano*

FIGURE 239. – A seasoned veneer sheet cut from tension wood in a Euramerican hybrid.

Courtesy *G. Giordano*



Italian data (Giordano. 1951) which refer to oven-dried dimensions, give an increase over the shrinkage for normal wood:

axial shrinkage: 0.8 % instead of 0.3 % for normal wood
radial shrinkage: 4.7 " instead of 2.8 " for normal wood
tangential shrinkage: 10 " instead of 7 " for normal wood
volumetric shrinkage: 15.5 " instead of 10.1 " for normal wood

The difference in axial shrinkage as compared with normal wood clearly explains the abnormal contractions which take place in planks with areas of tension wood during seasoning, and which often result in longitudinal cracks or in bending. On drying, however. the different rate of transverse shrinkage leaves a badly pitted surface with collapse cracks.

The mechanical characteristics of tension wood differ from those of normal wood in the same bole: Italian data (Giordano, 1951) give the following figures (at 12 percent moisture content):

Mechanical characteristics	Normal wood		Tension wood	
	real value	ratio value/density	real value	ratio value/density
Axial compression				
(average of 3 tests)	255 kg/cm^2	6.3	215 kg/cm^2	4.0
(average of 4 tests)	205 "	4.8	194 "	4.5
Bending strength (average of 4 tests)	510 "	—	455 "	—
Impact resistance (average of 5 tests)	2.9 kgm.	—	2 kgm.	—
Tensile strength parallel to grain (average of 8 tests)	572 kg/cm^2	—	622 kg/cm^2	—

Klauditz and Stolley (1955) give the following data for *P.* x *euramericana* cv. 'regenerata grandis':

Type of wood	Dry weight/humid volume g/cm^3	Lignin %	Cellulose %	Hemicellulose %	Tensile strength kg/cm^2
Normal wood	0.39	25.7	41.1	33.2	770
Tension wood	0.44	16.9	59.7	23.4	1,270

The authors emphasize that increased tensile strength only occurs in air-dried timber and not in green wood, and would appear to be due to a lack of cohesion between the ligneous wall and the gelatinous layer in green wood.

In regard to the formation of tension wood, it is generally believed that this abnormal tissue (as well as the compression wood of conifers) is produced as a result of a biological reaction to certain mechanical forces, such as the distribution of weight of the tree not being central on the base (due to an asymmetrical crown, a leaning bole or continual wind pressure). Recently it has also been thought that abnormal wood occurs as a result of pruning, but this theory is not satisfactory as it fails to explain the presence of this defect in trees which have never been pruned. Some authors do not exclude the possibility of a relationship between certain gelatinous fibers and bacteria; others, on the contrary, consider that exposure has a definite influence, as in France the northern face of the tree, and in Belgium the western face have this defect more frequently than other faces of the tree.

Very little is in fact known about the mechanism by which an external force acting on the ligneous tissues causes the wood cells to alter. Further, this question concerns pure, rather than applied science, and in any case does not concern poplars alone.

Here certain points need to be stressed:

1. In most cases tension wood occurs in reaction to certain mechanical forces. Nothing can be done about the wind, but the grower can reduce the extent of the defect by preventing the tree from leaning or being out of balance because of an irregular crown.
2. With the ever-growing expansion of intensive cultivation there is a definite impression that the ability to form tension wood is a specific, and hence hereditary character, and that some clones are more inclined to it than others.

Tension wood is one of the most serious defects of poplar wood because:

a) on felling, the presence of greatly strained areas causes the boles to split (unless precautions are taken by fixing on a Simplex type clamp);

b) on machining, the saw and especially the knife of the veneer lathe leave a cottony surface difficult to plane or pumice;

c) during seasoning, the planks develop pits and cracks, while the veneer sheet warps and splits much more than normal wood;

d) in the manufacture of pulp, tension wood gives a higher cellulose yield, but this is not always desirable as the final product, owing to its low hemicellulose content, is weaker and looks as though it has been boiled too long in caustic soda. In this case the digesting conditions have to be changed in order to balance the digesting requirements against the need to retain strength.

Very interesting data are given by Jayme in the following two tables:

TABLE 24. – COMPARATIVE YIELDS OF SULPHATE PULP FROM NORMAL WOOD AND TENSION WOOD (165°C.)

Species	Age (yrs.)	Type of wood	Gelatinous fibers in sample %	Yield of sulphate pulp %	Difference in yield compared with normal wood
P. charkowiensis	15-16	normal	6	52.51	+ 7.18
		tension	24	59.69	
P. trichocarpa	30	normal	0	54.01	+11.10
		tension	71	65.11	
P. x *euramericana* cv. 're-generata grandis'	33	normal	19	56.79	+ 5.64
		tension	71	62.43	

TABLE 25. – CHEMICAL ANALYSIS AND STRENGTH DATA OF CELLULOSE FROM NORMAL WOOD AND TENSION WOOD
P. x *generosa*

Components and characteristics		Normal wood	Tension wood
Chemical analysis			
Yield	%	52.01	59.84
Cellulose	%	74.91	88.81
Furfural	%	15.38	8.89
Lignin	%	3.11	1.57
Degree of brightness	×	22	41
Strength data			
Degree of freeness	°SR	50	50
(Length of time refined)	min.	45	52
Weight/Volume	g/cm³	0.858	0.642
Breaking length	m.	8,630	5,549
Folding endurance		2.450	46
Tearing resistance	cm.g/cm.	190	72
Bursting strength	kg/cm²	45.5	26.0

Tumors and cankers

See chapter on animal pests and diseases.

C. COLOR ALTERATIONS

Alterations in the color of wood of standing poplars may be the result of the initial stage of a fungal attack or of an accumulation of water in the tissues. A change in the color of wood occurring immediately after cutting may, however, be due to fungal attack or to the oxidation of the sap which circulated through the vascular tissue before felling.

While color alterations due to fungi start in the exposed parts of the wood, oxidation of the sap takes place wherever the air penetrates, and so also near the galleries of xylophagous insects, thus aggravating the damage they have caused.

Little is known, however, about the reason for the abnormal accumulation of water in the tissues, producing completely saturated zones, while the neighboring parts are not affected. Some authors attribute this phenomenon to bacteria. In fact, research in the United States on balsam poplars, where this phenomenon is known by the name of " wet wood," would seem to prove that the moisture content is higher and the bacteria more numerous than in normal wood but that there is no difference in the density of the two woods when seasoned.

FIGURE 240. – Color change due to an abnormal accumulation of water in the tissues.

Courtesy *G. Giordano*

A preliminary enquiry among industries in various countries would seem to show that the characteristics of the finished products are not affected by " black heart. "

As regards color alterations, reference should also be made to the chapter on insects and diseases. However, it cannot be sufficiently stressed that in order to avoid color alterations due to fungi, it is essential always to store the logs unbarked after treating the extremities with an antiseptic, or better still, to store them in water.

D. ALTERATIONS IN THE TISSUES DUE TO HAIL

Sometimes hail not only injures particularly soft bark but also causes changes in the first layers of wood under the cambium, which show up as reddish patches that spoil veneer sheets in particular.

E. DESTRUCTION OF TISSUES BY INSECTS, BIRDS AND PLANT PARASITES

See chapter on animal pests and diseases.

III. FELLING AND EXTRACTION IN POPLAR STANDS

FELLING

The technique to be used must be adapted to the type of stand. In natural forests or plantations where it is unnecessary to clear the soil of trunks and roots, clear-cutting is the most commonly used felling method. Frequently, however, in commercial plantations or even in rows adjoining

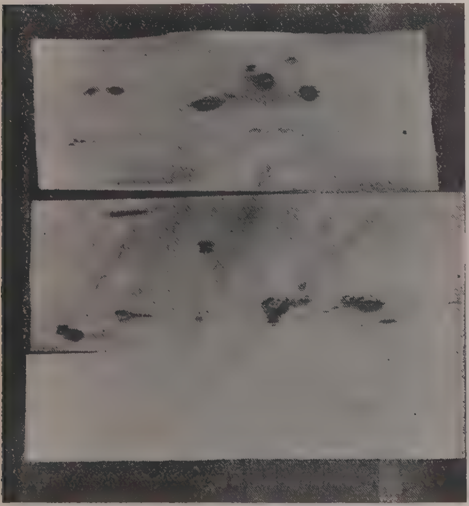


FIGURE 241. – Reddish patches in a veneer sheet caused by hail (the sheet was peeled from the log shown in Figure 242).

Courtesy *G. Giordano*

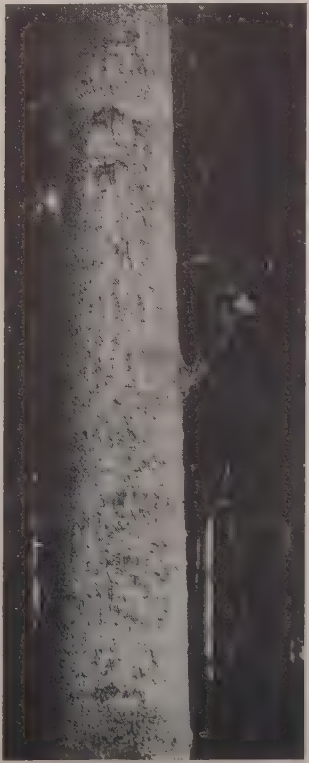


FIGURE 242. – Poplar bark damaged by hail.

Courtesy *G. Giordano*

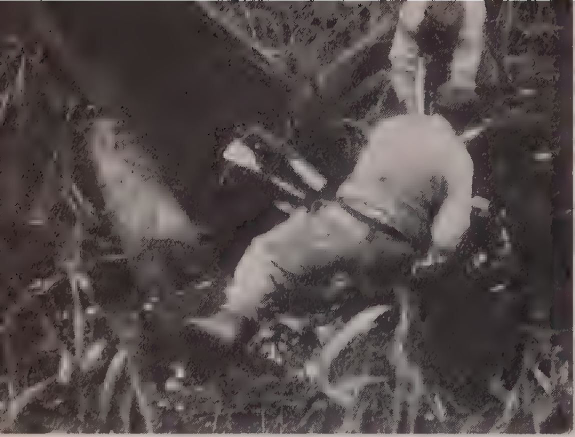


FIGURE 243. – Binding the base of a markedly leaning poplar with a chain before felling.

Courtesy *G. Giordano*

farm land, the ground has to be cleared of obstructions for the crop that follows, in which case felling must be followed by grubbing.

Clear-cutting

Established techniques for the use of axe and saw for felling forest trees should be used in poplar stands, with certain precautions imposed by the nature of the species.

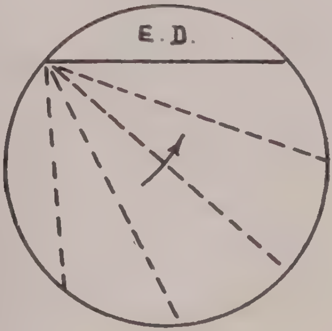
Generally, there is no need to remove flares and spurs (except for *P. nigra* 'italica') because the basal section is usually round.

For very straight stems, undercutting with an axe to bring the tree down in the correct direction, need not be more than $^1/_4$ or $^1/_5$ of the diameter. Crosscut sawing on the opposite side should be a few centimeters above the bottom of the undercut section, and special attention should be paid to removing the two ends of the butt hinge, between the axe-notched section and the saw cut, before the tree falls. It is at these two ends of the hinge that the trunk holds to the roots until the last moment. In the last portion to hold together, the fibers are generally bent and large splinters may be torn out from the stump log. Therefore, before the sawing is finished and before driving in the wedges that give the direction of fall to the tree, the saw should be drawn across once or twice, or a few blows of the axe given to cut these bent fibers attaching the trunk to the base at the ends of the hinge.

Even this precaution is not always enough to prevent the occurrence of longitudinal cracks when the tree falls, particularly when the lean of the tree, an asymmetrical crown, or a steady wind blowing from a certain direction, has caused the woody tissues to form tension wood. Whenever there is danger that when the tree falls splitting may occur, which will lower the value of the wood (for example a veneer log), it is advisable before starting to fell, to bind the base of the tree with a constricting cable or chain held taut by simple wooden wedges. When the tree has been felled, it is necessary, before removing the chain or cable, to make a hole from 12 to 15 centimeters deep with a borer 2 to 3 centimeters in diameter in the cut section along the line of the pith.

On trees leaning in the chosen felling direction, the undercut notched with the axe should be narrow but deeper than usual (4/10 of the diameter), and it is best to continue to as much as 8/10 or 8.5/10 of the diameter with the crosscut saw. Because of the weight of the tree, two wedges must be put at the outer sides of the undercut immediately prior to sawing, which is begun on the side opposite the undercut (or, even better, on the slant), working very fast to lessen the danger of longitudinal splitting.

FIGURE 244. – Method of felling with a chain saw. E.D. = undercut on the side of the fall.



If the direction of fall does not coincide with the natural lean, more wood must be left on the portion opposite the line of inclination, and a cable or wedges used to support the tree.

Generally, such precautions suffice to make the entire trunk usable without losses or waste during felling, as well as preventing damage to neighboring trees. In this connection it should be remembered that frozen poplar is brittle and breaks easily.

Felling is usually carried out by a two-man team equipped with axe and saw.

If, instead of axe and crosscut saw a chain saw is used, the method does not vary greatly. After the shoulders have been removed, an undercut is made with two sawings, and then the final sawing is done, starting from the side opposite. If the tree is not leaning, and in removing the shoulders the ends of the hinge are cut, the saw can be applied as shown in Figure 244; otherwise it is necessary to work from both sides of the butt hinge in order to finish parallel with, and exactly opposite, the undercut.

The chain saw has the advantage of rapidity in the final stages, so that bursting and splitting are minimized when the tree falls.

The choice of saw and the make-up of the sawing team depends on the size of the trees to be felled: for trees over 25 centimeters in diameter at breast height a two-man team is recommended.

In the Scandinavian countries a bow saw is used and no special technique is necessary for felling poplar with it.

There is one case in intensive cultivation when clear-cutting is necessary: namely, in rows along canals where, for obvious reasons of soil stability, stump removal is inadvisable. However, if the stump is left in the ground there is a danger that after some time tunnels will be formed around the roots, having a detrimental effect on water retention and even possibly weakening the river banks. It has been suggested that stumps be treated with chemical or organic products to make the roots rot down quickly and be turned into humus without leaving holes in the soil. However, it is as yet premature to advise for or against this method but it is one which deserves attentive study.

Felling followed by grubbing

When poplars are grown under a scheme of intensive cultivation and particularly when, during the early years, they are interspersed with farm crops, it is essential that all roots should be eliminated at the time of felling. This is an expensive job that is only economic if carried out at the same time as felling.

The workman begins by digging a hole around the tree with a pickaxe to uncover the big roots, which he then cuts with the axe. The hole is deepest on the side toward which the tree is to fall because the tap root has to be cut on that side. Generally, the hole around the base of the tree is not big enough for a workman to operate in easily. He has to stand on the ground and cut the roots in the hole with an axe having a long handle of 1 to 1.10 meters. Sometimes the tree does not pull when the roots are cut; a rope must then be tied around the trunk 2 to 3 meters above the ground. Usually, if this is pulled taut it can effectively guide the precise direction of the fall, but the method cannot be used in all cases because it involves a considerable waste of time. In fact, while it takes only one man to dig a hole, three to six workers are needed to pull the cord, which means that their work on other trees is interrupted.

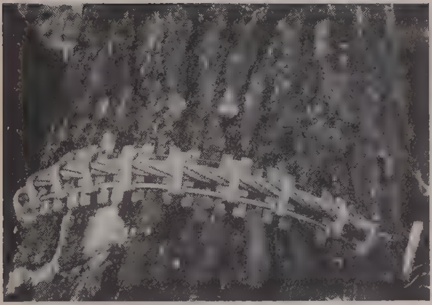


FIGURE 245. – Protective belt used when uprooting trees by cable and tractor.

Courtesy *G. Giordano*

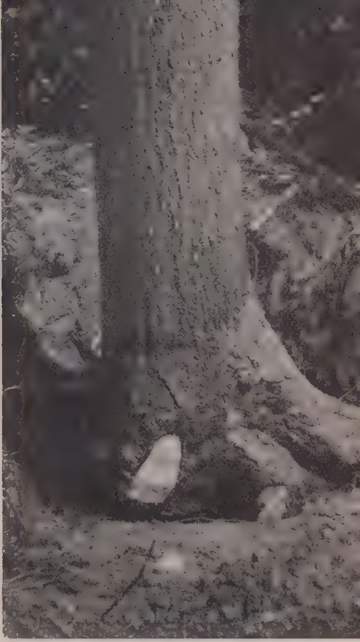


FIGURE 246. – Poplar ready for uprooting.

Courtesy *G. Giordano*

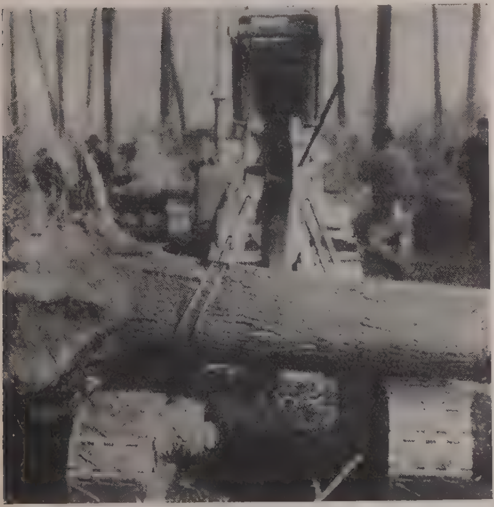


FIGURE 247. – Extracting by tractor.

Courtesy *G. Giordano*

The soil from the hole should be piled into a small mound on the side on which the tree is to fall. This helps to lessen the shock of the fall and at the same time to raise the stump a little in order to make cross-cutting easier for the sawmen. The same purpose can be achieved by placing at the foot of the tree, at right angles to the direction of fall, a bolt on which the felled tree can rest.

If a tractor with a winch is available, felling and stump removal can be combined by hauling with a cable. If the soil is sandy and light, and

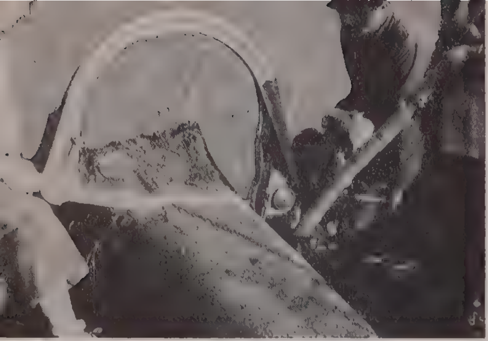


FIGURE 248. – Crosscutting by chain saw.

Courtesy *G. Giordano*

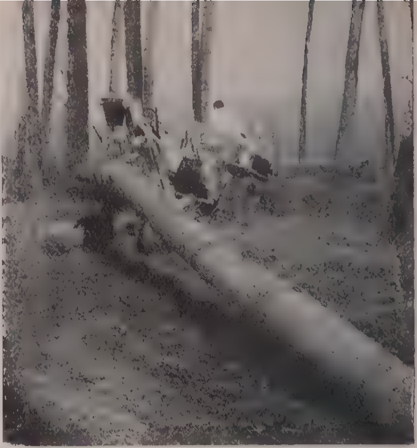


FIGURE 249. – Extracting poplars by tractor.

Courtesy *G. Giordano*

the roots are not very deep, hauling alone will be sufficient but otherwise the large roots have to be cut prior to felling. In any case, the tractor can haul away whole trunks with their roots immediately afterward, which has some advantages.

The correct method should be used when stumps are removed by tractor: the cable should be attached 2 to 3 meters from the base over a belt to avoid possible damage by the cable not only to the bark but also to the timber. The pull on the stump should not be applied suddenly but by repeated, progressively increasing tension. Further, the cable must not be attached too high or the tree may bend instead of being uprooted, while there is a risk of the fibers, or even the tree itself, breaking.

REMOVAL OF BRANCHES

Depending on the felling tools used and the workmen's usual practice, large branches can be lopped off either with an axe or a saw, and small ones with a billhook.

Branches that cannot be used for timber and in industry, can be used for fuel. Conversion practice differs in each country and cannot be discussed in too much detail here.

Crosscutting

Crosscutting is carried out generally by a two-man team, as soon as each tree has been marked for the produce it is to yield. It can be done with either a crosscut or a chain saw. The latter obviously has several advantages, in particular its speed of operation, which lessens the chance of rupture and dislocation of fibers.

Data are available on the time for felling, removing branches and crosscutting poplar, in a clear-felling (Müller-Thomas) and for combined felling and stumping, branch removal and crosscutting (Giordano), in minutes.

TABLE 26. – WORKING TIME FOR POPLAR FELLING AND PRELIMINARY CONVERSIONS *

Unit	Average volume of the tree with bark, in solid m³				
	up to 0.10 m³	from 0.11 to 0.20 m³	from 0.21 to 0.50 m³	from 0.51 to 1 m³	more than 1 m³
Solid m³	584′	130′	98′	66′	55′

* According to Müller-Thomas.

TABLE 27. - WORKING TIME FOR POPLAR FELLING AND PRELIMINARY CONVERSIONS*

Unit	Average volume of the tree with bark, in solid m³							
	0.4	0.5	0.6	0.8	1.0	1.5	2.0	3.0
Solid m³	188′	172′	112′	149′	141′	131′	126′	120′
Single tree	75′	86′	97′	119′	141′	196′	251′	361′

* Giordano.

The comparison of these figures shows the considerable importance of the choice of technique which is imposed by soil conditions, the methods of cultivation and the produce classes. In general, the produce classes are larger in Germany than in Italy, where in the crosscutting of logs for peeling, sawing and the paper industry, they are considered together.

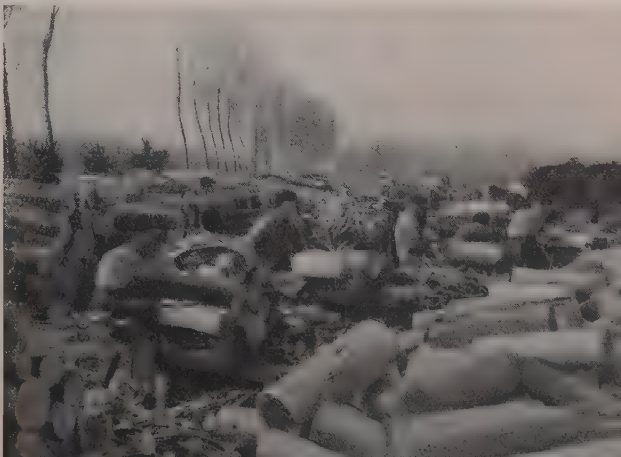


FIGURE 250. – Timber yard where poplar billets are barked by hand.

Courtesy *G. Giordano*

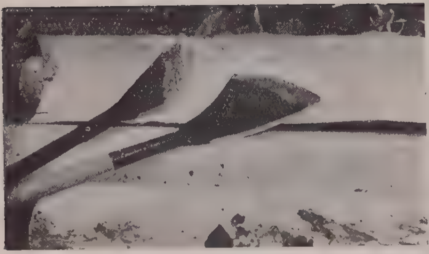


FIGURE 251. – German knife for barking poplar.

Courtesy *G. Giordano*

BARK REMOVAL

Barking of poplar is not always done at felling time; in many places logs and billets are removed from the forest unbarked, as the operation is best performed in the timber yard. Frequently, therefore, machines and typical industrial plants are used for barking.

However, there are instances when it is necessary to bark the trees in the forest. The effect of season of felling on the ease of barking is well known but only rarely can the felling time be chosen with this in mind. Generally, therefore, trees have to be barked whenever possible and large fixed machines cannot be used but, at best, mobile types with knifes mounted on a wheel, disc or other system. For barking by hand, either the axe, billhook, two-handled knife, or any other implement with a blade can be utilized. There are, of course, particularly well-designed tools for this purpose, such as the German or Scandinavian blades. If, however, the working time is considered in relation to the inevitable wasted periods, it is not always more economic to use a machine than manpower; sometimes a well-organized timber yard, where barking is done by hand, can be just as efficient. On this subject Müller-Thomas gives the following working times:

Time required for barking 1 m² of surface

With barking iron, of billets for paper (in the forest)	1 minute
With ordinary barking iron	2 "
With axe for large sizes of timber	3 "
With barking knife of billets for paper or pulping (complete barking)	9 "

According to Giordano, it takes 2.8 minutes to bark 1 m^2 of peeling logs (average diameter 32 to 40 centimeters; length between 1.80 and 5.50 m.) with an axe a few weeks after felling, 7 minutes to bark pulpwood billets with a knife, and 8.4 minutes to bark billets with a billhook.

The cheapest method of barking is probably chemical, that is to say, by applying certain substances to standing trees. By this method, when the sap is running, a strip of bark is removed and to the exposed wood is applied a solution of a chemical such as sodium arsenite, sodium monochloroacetate, etc. After a few weeks, at the most three months, the tree dies and the bark can be completely and easily removed without using machinery or tools.

The results obtained in North America, using this method when utilizing poplar for paper pulp, were satisfactory. In Europe, no complete data have yet been assembled but the impression from preliminary trials is on the whole favorable. Nevertheless, some points still have to be clarified; namely, whether there is any danger that dry standing timber will be quickly attacked by insects and fungi, whether there is a risk that chemical treatment will discolor the wood, etc.

PROSPECTS FOR IMPROVING FELLING PRACTICES

The first factor in improving felling practice is the proper choice of tools. In this connection, it should be mentioned that the present trend in some countries of central and northern Europe is to use light axes for felling, which increase the worker's efficiency. Nevertheless, the long-handled axes with heavy but narrow heads used in northern Italy have proved their worth, because the feller working at ground level has to cut the springy wood of the roots deep inside the hole. As regards saws, both for felling and crosscutting, the crosscut saw with four cutting teeth and one planing tooth can be used for crosscutting and for soft woods (except for the small poplars of northern Europe) and with two cutting teeth and one planing tooth for felling and for hard woods, such as certain types of *P. nigra*.

As for the use of chain saws in poplar stands, in view of the size of the trees and for efficient organization of the work, it always appears advisable to use a two-man saw, as extra weight is of no importance on ground which permits easy sawing conditions. The type of chain saw with the chain moving along a fixed groove at the two sides of a bow has proved particularly useful in crosscutting large billets, because the chain rarely jams.

Whereas in poplar stands in which the owner supervises the felling, when traditional methods cannot be changed, in industrial plantings mechanization is the basis of efficient work. A properly equipped tractor can be used for combined felling and stump removal, for hauling whole trees (with roots and crown) to the timber yard and for loading the billets onto trucks. By carrying out these operations at the same time and place, good organization and specialization of work is obtained, which is of great importance. Clearly, however, a tractor with a winch and the equipment listed below is necessary:

a) a sufficiently long cable (over 80 m.) and a protection belt;

b) shorter cables for removal of stumps, with a choker hook and end hook for ground haulage;

c) a logging arch on caterpillar tracks or wheels for haulage of partially suspended trees;

d) cables and pulleys for mechanized loading with power take-off on the tractor and sliding grooves.

Finally, if the billets are to be loaded directly onto the truck, a lift loader in front is required, of the fork-lift type for example.

When felling is completed, the tractor can also do other heavy duty jobs, such as moving earth to level the ground, filling in the holes and digging fresh holes for new plantings. For this purpose an angledozer blade that can be mounted on the tractor, and an auger for boring the holes are necessary.

Experience in this work in the Po Valley has proved that integrated, mechanized operations as described above can give very good results both from the technical and financial point of view. Mechanization enables felling and cultural operations to be carried out speedily at the right time of the year, independent of manpower considerations. For instance, the preparation of pits for new plantings, of the size required to allow the insertion of well-grown plants, requires considerable manpower: a worker can only dig from 12 to 20 holes a day, while an auger can prepare pits 70 centimeters in diameter and 90 centimeters deep at the rate of 250 to 300 a day.

A special type of tractor is not required for mechanization of work in poplar stands but it should be of not less than 25 to 30 h. p. and capable of mounting the equipment listed above.

IV. UTILIZATION OF POPLAR WOOD

The many uses to which poplar wood can be put may be grouped into two categories: in large-scale industrial enterprises that require raw material in considerable quantities, and for the small artisan or family enterprise.

The large industries, listed in the order in which they developed historically, are:

- *a*) the building industry (the earliest);
- *b*) the sawmilling industry;
- *c*) pulp and paper industries;
- *d*) the veneer-peeling industries (including matches, plywood and box making);
- *e*) the board-making industries using wood, fibers or waste (the most recent).

The secondary industries are:

- *i*) box making;
- *ii*) sabot manufacture;
- *iii*) wood flour.

THE BUILDING INDUSTRY

In past centuries poplar wood, particularly black poplar wood, has found many uses in building, such as for beams for roofs or ceilings, and as pilings. As regards durability, it has already been mentioned that the foundations of many houses in Venice are of poplar piling and can compete with piling of larch, oak or alder. The use of poplar for crossbeams, particularly of *P. nigra* cv. ' italica ', was very common in the past, from western Europe to the Near East, and in this connection it is an interesting fact that poplar hardens with time to such a degree that frequently it cannot even be nailed.

Poplar is still widely used for construction purposes in Mediterranean countries and the Near East, either as crossbeams for roofs and ceilings or as a framework for cob or mud walls. In the Near East, large-sized timber is not used and beams with a diameter of 15 to 25 centimeters are quite adequate, provided the bole is very straight, as is the case with ' Hamoui ', a local black poplar in Syria.

In southern Spain, poles 13 to 15 centimeters in diameter, cut into lengths of 4.20 to 5 meters, are used for roof construction.

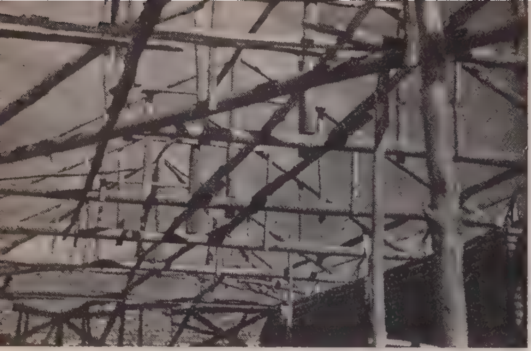
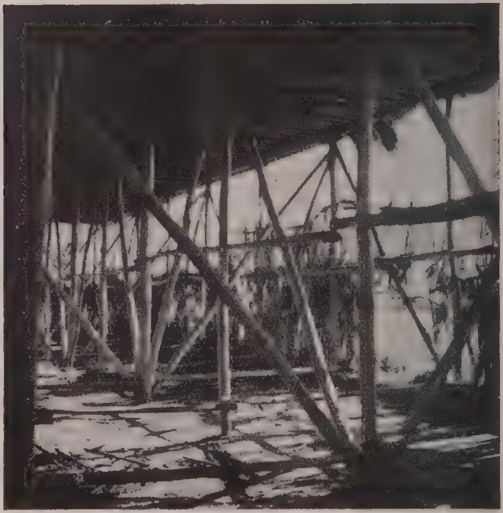


FIGURE 252. – Framework of poplar wood in Teheran.

Courtesy *Sabeti*

FIGURE 253. – Shed made of poplar wood for drying tobacco (region of Granada, Spain).

Courtesy *G. Giordano*



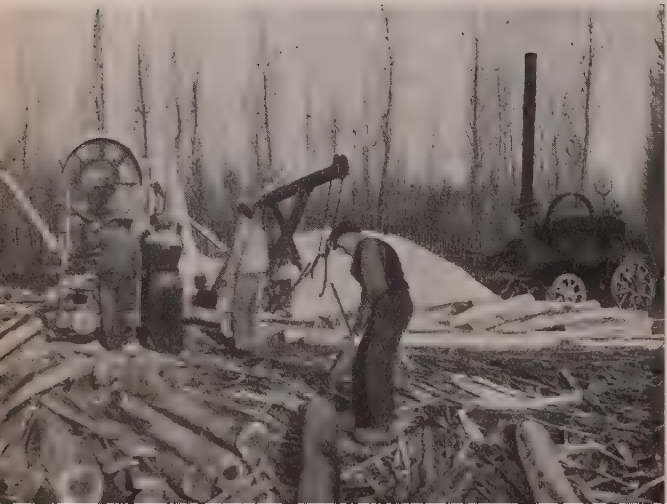


FIGURE 254. – A mobile saw in operation in a poplar stand.

Courtesy *G. Giordano*

Because of the great shortage of wood in the Near East, local poplar of good habit is recommended for electric power poles and has already been put to this use in Iran. However, an inexpensive method of impregnation or antiseptic protection is needed.

Poplar planks are mainly used in temporary constructions such as scaffolding and frameworks, as will be seen in the following section.

SAWMILLING INDUSTRY

Poplar wood is more widely used in the sawmilling industry in countries which are poor in coniferous forests.

Logs are generally grouped according to their final use and not merely by their size but above all on the basis of the quality of the wood. For sawn timber, large or medium-sized logs are acceptable (diameter over 20 to 22 cm. in Germany, 18 cm. in Italy) in which certain color defects, tension wood, a limited amount of insect attack and so forth are tolerated.

Very often in north Italy (Po Valley) and in France, logs are sawn on the spot (with or without prior barking) by mobile saws. While in Italy crosscutting is generally done by hand with a crosscut or a chain saw and the timber cut into boards by a band saw driven by a wood-fired engine, in France motor-driven crosscutters are used initially and then a vertical or horizontal band saw is used to cut up timber into boards, then finally a small circular saw is used for trimming the ends (butting). The planks obtained are then cross-tacked vertically (like a letter x) for preliminary seasoning and later transported to a permanent timber yard, where they are stacked in square piles. In Italy planks range from 2-2, 5-3 meters in length and from 20 to 50 millimeters thick.

In France the length is 2, 2.33, 2.66 meters, with a thickness between 13 and 60 millimeters. Elsewhere the logs are transported to sawmills, stacked and then converted by various saws or by band saw. In France, permanent sawmills generally have one or more band saws with a dividing carriage in order to plain-saw the butt logs, and one or more sets of saws consisting of two band saws on a movable table and one ripsaw to square the billets.

In Spain (Granada), large-sized timber reserved for sawing into planks (less than 30 cm. diameter however) are sawn into lengths of 2.50 meters.

In some countries the planks are merely left to dry in the air to season, since the woody tissues of poplar lose water rather quickly. In winter, after three months in the open (provided that the stacks are protected from the rain and the planks separated by sufficiently large and dry strips of wood), and in the summer even after one month (in northern Italy and France), the moisture content takes longer and for this purpose artificial drying is sometimes advisable.

In other countries, particularly in Belgium, Germany and Switzerland, kilns are often used. If the wood is still very wet, low temperatures (60° C.) are best with a high speed of air circulation (0.75 m/sec.): if the moisture content of the wood is low, the temperature should be lowered even further (40-50° C.) in order to prevent the wood from turning brown, and if the wood is abnormally dry, then the temperature should not exceed 30° C.

To speed up initial moisture evaporation or loss of free water in the cells, extraction of water under pressure between two rollers is recommended: for this purpose the wood must be free of knots and less than 18 millimeters thick.

High temperature drying (at over 100° C.) recently introduced into the timber industries has been used successfully for softwoods. With 25-millimeter boards, the moisture content can be reduced within ten hours from 60 percent to 12 to 15 percent.

Poplar wood is always sawn into planks. It is not advisable to use squared beams of poplar for permanent construction.

The classification used widely in France for sawn timber is as follows:

a) choice wood: completely free of tension wood, 80 percent free of all defects;

b) good wood: free of tension wood but with some sound knots;

c) wood for box making: may contain some tension wood.

Sometimes these categories are further subdivided; for example, under good wood, there may be " small good wood, " and under box making " good " and " ordinary " box-making wood. Some boards may even be excluded from the category " ordinary box making. " There is on an average 5 to 6 percent of " choice, " 35 to 55 percent " good wood, " and 40 to 60 percent " box wood. "

In Belgium (Hasselt), after sawing, the wood is separated into " sour " wood (wood that is expected to warp and is cottony, i. e., tension wood) and " sweet " wood. Before seasoning, the sawn timber is graded as follows:

i) first choice: two sides and one face free of knots and " sour " wood;

ii) second choice: some small knots;

iii) third choice: knotty and " sour " wood.

After drying, the wood is divided into five grades: the first and second are used for furniture making, the third and fourth for boxes and the fifth for pitprops in coal mines.

In stacking, considerable attention should be paid to the prevention of attack by fungi, which occurs if the billets and planks are not raised well above the ground or if the stack is in a particularly damp place. Bark and branches that have been removed must be cleared from the timber yard and no vegetation must be allowed to grow between or under the stacks. Care must be taken to see that water drains off immediately.

A considerable quantity of second-grade sawn timber of poplar is used in box making; for example, cases, open crates, casks and barrels for dry products, etc. First-grade sawn timber has more important uses: drawing tables and drawing boards, ordinary furniture, carpentry and interior woodwork, furniture frames to be covered with fine veneers, cornices, flooring of railway wagons and coach bodies, prepressed sheets between rails and railway crossties (sleepers), frames and vats for tanning, etc.

In big fruit- and vegetable-producing countries, such as Italy and France, the manufacture of open crates is very important and several institutes of box making and wood technology laboratories have made a study of uniform standards, mainly for the purpose of reducing losses and market gluts and of rationalizing the method of manufacture.

CELLULOSE PULP AND PAPER INDUSTRIES

The following very interesting data were given by Messrs. Campredon, Jacquiot and Vilars in a report presented by the French delegation to the Seventh Session of the International Poplar Commission:

> ### *The poplar in papermaking*
>
> In this article we are setting forth briefly all the possible technical uses of poplar without considering the financial side, though this is of prime importance.
>
> Poplar can be processed into mechanical, chemical or semi-chemical pulp. Since its fiber is shorter than that of the conifers, all the pulp will have less resistance to tearing, but its tensile strength may, in some cases, be practically the same.
>
> #### *Pulp obtained from billets*
>
> ##### *White mechanical pulp*
>
> Poplar wood provides primarily a filler pulp which has proved valuable for certain types of paper: tissue paper, writing paper, etc. It imparts bulk, absorption, opacity, *épair* and smoothness. As its resist-

ance is of no consequence, only the work output per woodsman counts, so that a sufficiently cheap pulp can be obtained. In the United States, such pulp is used at the rate of 10 to 25 percent in tissue paper and coating paper. The paper produces a considerable amount of powder, a defect which can be overcome if necessary.

In Italy, the pulp is also incorporated in printing paper and newsprint at the rate of 10 to 40 percent, with a cellulose content ranging from 35 to 50 percent. The paper machine processes it at a maximum speed of 220 meters, and the weight per square meter is more than 52 grams. In France, where the manufacture of newsprint would not be possible under these conditions, where the press enforces a gram weight of 50, a pulp content of not more than 15 to 20 percent, and a speed of manufacture of between 330 and 410 meters are required for it to be economical. The United States and Canada do not incorporate hardwood mechanical pulp into newsprint.

In the United States and Italy, mechanical pulp from poplar and aspen is generally bleached, either with hydrogen peroxide or hydrosulphite, thus whitening the paper from five to ten points by these respective methods.

Brown mechanical pulp

This pulp is valuable in the manufacture of cardboard and has long been used in Germany for this purpose. The billets are steamed in digesters for some time and ground like ordinary mechanical pulp. Due to the softening of the connective matter between the fibers and the swelling of the fibers, less motor power is needed and the brown pulp obtained is definitely more durable than the preceding pulp.

	Tensile strength	*Tearing strength*
White mechanical pulp	1,200–1,800 m.	20–30
Brown mechanical pulp	4,000–5,000 m.	50–60

However, its very dark color cannot be bleached and a certain fragility limits its use to certain types of cardboard.

Mechano-chemical pulp

This type of pulp is still in the laboratory stage. Instead of vat digestion of the wood, as for brown pulp, the billets are cooked in a sodium sulphite and bicarbonate solution at 170° C. in a strong vacuum, and the liquor is forced in under pressure so that it penetrates the billet. After it has been cooked, the billet is ground and its fibers removed.

The advantages of this pulp are its clear color, its ability to bleach and its slightly greater strength than brown pulp.

It is still too early to specify to what use it can be put other than for the manufacture of cardboard.

Pulp obtained from chips

Neutral sulphite pulp

Billets cut into chips are cooked at 170° C. in a buffered solution of sodium sulphite. The pulp is then crushed and refined in disc refiners.

In the United States, 90 percent of such pulp (made of birch and aspen) is used in the manufacture of corrugated cardboard. In France,

TABLE 27. – POPLAR PULPS

Process	Yield %	Color	Elmendorf tearing strength	Tensile strength m.	Properties	Defects
Mechenical	95	Light ecru	20-30	1,200 – 1,800	Bulky, soft, opaque, good *épair*	Fleeciness, powdery, lack of strength
Brown pulp	90	Deep brown	50-60	4,000 – 5,000	Somewhat fragile	Very dark color
Mechano-chemical	80	Yellowish ecru	60-80	4,000 – 5,000	Greasy, transparent, crispness	Bad draining, lack of suppleness and opacity
Neutral sulphite	60 to 70	Yellowish ecru	70-90	3,000 – 8,000		
Bisulphite	50	Light ecru	70	2,000 – 6,000	The pulp can be used directly because of its light color and *épair*	Not very strong
Unbleached kraft	45	Brown	100	4,000 – 10,000	Solid; soft, absorbent, opaque, bulky, good *épair*	
Bleached kraft	40	White	100	4,000 – 10,000		
Cold soda	85	Light ecru	50-60			

For comparison purposes, spruce pulp has the following properties:

	Tearing strength	*Tensile strength*
Mechanical	50	3,500
Bisulphite	120	4,000 – 11,000
Kraft	220	4,000 – 10,000

straw is used for this purpose to a large extent. The remaining 10 percent is bleached and a small percentage (from 5 to 15 percent) is mixed in with other types of paper (coating paper, paraffin paper, magazines, etc.). This so-called monosulphite pulp is greasy, difficult to wash, and drains poorly on the machine but it imparts crispness, stiffness and transparency to the paper.

Bisulphite pulp

Bisulphite processed poplar produces a clear, rather strong, pulp (2/3 of spruce [*Picea*] bisulphite) which may find an outlet in the paper industry. One factory in France manufactures this on an industrial scale.

Kraft and soda pulps

Treatment with alkali, particularly by the Kraft process, produces strong pulps which can be used in many types of paper.

Judging by what is being done in the United States, it appears possible to incorporate unbleached alkali-treated pulps in tissue paper (sanitary towels), gummed papers, etc.

When bleached, it can be used in making coating paper, offset, envelopes, paper towels, crepe paper, napkins, etc., to the extent of 10 to 30 percent, or even more in some cases.

Cold soda pulp

This entirely new process is still at the laboratory stage. It consists of soaking rather small chips in a caustic soda solution for four to six hours at 20°C. (or 90°C.), grinding them in a Bauer rotary disc mill, and then refining the pulp. (The two discs turn in opposite directions.)

The yield is excellent (85 percent), the strength fairly good; the pulp may be used in the munafacture of cardboard.

Conclusions

The appended table summarizes what has been said above, giving figures and a comparison of the properties of the different kinds of poplar pulp.

However, this is not the only tree species that can be used. Birch, hornbeam and lime, among the broadleaved species, give pulps that are as good or even better, and bleached chestnut is used industrially in France. The density of poplar pulp is rather low, that of birch rather high, and therefore birch gives a better yield per unit treated volume. However, poplar has the advantage in that it gives a clear pulp and it is the only broadleaved species that can be used for mechanical pulp.

There are a certain number of advantages in adding hardwood pulps when making paper and cardboard (*épair*, bulk, softness, absorbency, ink taking, opacity, and sometimes, stiffness, and transparency for the sulphites), but it should not be forgotten that only a small percentage can be incorporated as they are outclassed by the softwoods, while straw is sometimes a competitor.

The cost price has to bear a relationship to their properties and low strength if they are to compete on the paper market.

Similarly, German data prove the possibility of using poplar in the manufacture of paper. Dr. Brecht's report to the International Poplar Congress at Cologne in 1953 says:

> In grinding, the poplar species we used in our preliminary experiments require less power than does spruce wood. When the minimum power necessary is used, a free pulp with relatively long fibers is obtained. This pulp, however, has a high sliver content, and the fine stock (*Feinstoff*) is composed mostly of fines (*Mehlstoff*). Consequently, this pulp is weaker than the mechanical spruce pulp made under the same conditions. The features of poplar pulp sheets are a relatively low density, softness and high absorbency; compared with spruce pulp sheets, they seem less bright.
>
> Even by using more power than is necessary, it is not possible to make really strong poplar pulps. Still, the pulp can be used when softness and absorbency are required and when the lack of strength matters little, for instance, in the manufacture of many kinds of printing papers. Future experiments may possibly indicate a way of augmenting the strength, for example, by means of better mixtures of poplar mechanical pulp and greasy spruce, mechanical pulp or of mechanical pulp and incompletely beaten bisulphite pulp or of normal and greasy poplar pulp. We intend to continue our studies along these lines and at the same time to examine other species of poplar, other grinders and other methods of milling with these grinders.

Lastly, Jayme reports (*Das Pappelbuch*):

> The chemical process to be employed depends on the end use of the pulp. The acid sulphite process definitely produces a much weaker pulp than does the alkali sulphate process. Therefore, the latter is to be preferred when pulp for very strong paper is wanted, while the sulphite process should be used for obtaining pulp for synthetic fibers. The soda process, of course, produces pulp that can be used for making lightweight printing paper (bible paper).
>
> In converting *P. tremuloides* into mechanical pulp for printing paper, the Forest Products Laboratory at Madison has found that it is better to use a smooth surface grinder which, for a certain grade timber, requires less power than a coarser grit grinder, while giving a higher output.
>
> More power is required to produce a pulp of the same strength from poplar than from spruce. If, however, poplar and spruce are ground under the same conditions, poplar yields a finer but weaker pulp, owing to the shorter fibers, and requires less power per unit of weight.
>
> The same laboratory has experimented with poplar wood to make a chemico-mechanical pulp. The process consists in cooking the chips and then grinding them mechanically. Cooking in a neutral solution has produced 55 to 58 percent of bleached pulp, comparable in strength to coniferous woods.
>
> Experiments conducted at the *Cellulosa Argentina* Laboratory have proved that by using the neutral sulphite process, poplar (and willow) wood can be converted into a chemico-mechanical pulp, the degree of brightness of which depends on the cooking. With less sulphite and NaOH, a pulp higher in color and coarser but difficult to defiber is obtained. The right proportion of NaOH for a good cooking is 10 percent. The pulp is improved and bleaches easier if it is cooked longer at maximum temperature.
>
> If no great strength or exceptional brightness are required in a pulp, calcium hypochlorite can be used for bleaching. Bleaching chemico-

> mechanical pulp by oxidation is cheaper than using chlorine, and increases the output.
>
> The grade or hardness and the grain size of the grinders affect the qualities of the mechanical pulp and should make it possible to obtain a very strong paper; the *Cellulosa Argentina* Laboratory has apparently found that a coarse grit, artificial stone grinder dressed at reduced speed for 62 seconds will give the maximum strength for seasoned wood. However, the better quality of pulp obtained is offset by greater wear on the grinder and burr, a lower output, and consequently a combination of adverse economic factors.

Tables 28 and 29, contributed by the same author, contain very interesting data.

TABLE 28. – DETERMINATION OF THE CELLULOSE CONTENT IN A SAMPLE OF POPLAR WOOD (JAYME)

P. x *euramericana* cv. ....: all figures based on extractive-free wood

Wood analysis	
Alcohol and benzene extract	2.34 %
Lignin	22.01 "
Furfural (HBr method)	12.93 "
Pentosans (Furfural x 1.375)	17.78 "
Holocellulose	
Holocellulose yield	80.97 "
Holocellulose lignin in relation to extractive-free wood	4.03 "
Lignin-free holocellulose	76.94 "
Raw cellulose	
Alkali-soluble hemicellulose and lignin	32.55 "
Raw cellulose yield	44.39 "
Pentosan content in raw cellulose, determined on the wood	0.91 "
True cellulose	
True cellulose yield	43.48 "

TABLE 29. – VARIATION IN CELLULOSE YIELD OF SULPHATE PULP FROM THE SAME TRUNK (JAYME)

No.	Species or type	Age (yrs.)	Total height m.	Cellulose yield of sulphate pulp from same trunk			+ or — yield compared with lower part
				base %	mid-height %	top %	
1	*P.* 'serotina'	10	15	58.91	57.11	56.09	–4.79
2	*P.* 'robusta'	10	—	57.65	56.06	54.36	–5.88
3	*P. trichocarpa*	30	18	57.53	56.39	54.37	–5.49
4	*P.* 'robusta'	17	20	56.85	55.60	55.13	–3.03
5	*P.* 'serotina'	17	17	56.47	55.16	54.99	–4.39
6	*P.* 'robusta'	9	11	55.85	55.00	54.59	–2.26
7	*P.* 'serotina'	10	—	55.69	53.29	51.38	–7.74

The various varieties of poplar are a better raw material for paper making than beech and come closer to spruce, except for length of fibers. The high cellulose content of some types indicates that it is really advisable to use them to obtain pure cellulose; this has still to be studied from the chemical point of view. They can, however, be used for semichemical and mechanical pulp.

In new stands it is important that 10-year-old wood should have attained its full cellulose content. For this reason, even from a chemical standpoint, the cultivation of poplars at close spacings on suitable soils with proper care is justified, then after 8 to 12 years (but in all cases before growth stops) they can be thinned to obtain fibrous wood.

Boessneck, Brossa and Viviani in Italy, using the soda process, obtained the best results with *P. alba* rather than with black poplar or the Euramerican hybrids. The findings of paper-making tests at the laboratory of the *Cartiere Burgo* (Burgo papermill) with various Euramerican hybrids grown in northern Italy are given below:

Soda pulp

P. x *euramericana*	'I-214'	'I-37'	'I-455'	'I-476'	'I-488'	'I-154'
Total fibrous matter (%)	53.4	51.0	49.6	55.6	50.5	52.8
Rejects (%)	0.17	0.03	0.13	0.10	0.12	0.14
Degree of cooking °Roe	1.6	2.0	2.4	2.7	3.6	2.4
Freeness °SR	26.0	33.0	25.0	35.0	50.0	32.0
Apparent density	0.831	0.905	0.829	0.903	0.925	0.869
Breaking length (m.)	8,220	7,960	8,010	7,830	6,870	6,930
Stretch (%)	2.37	2.97	2.50	2.80	3.12	2.95
Bursting strength (m^2)	40.9	41.0	40.1	40.6	34.1	36.9
Folding strength (No.)	104	440	483	277	260	215
Breaking load (grams)	41.8	58.9	56.2	57.2	57.5	83.3

Monosulphite semi-chemical pulp

Total fibrous matter (%)	73.0	70.7	74.7	70.7	74.4	76.1
Apparent density	0.971	0.925	0.962	0.969	0.925	0.912
Breaking length (m.)	10,510	10,140	10,340	10,230	9,100	9,480
Stretch (%)	4.55	4.40	4.45	5.20	4.45	4.72
Bursting strength (m^2)	68.6	64.6	68.3	75.2	56.8	56.3
Folding strength (No.)	2 260	2 470	2 270	3 900	2 230	2 760
Breaking load (grams)	52.6	60.4	56.8	57.0	70.7	61.9
Refining (min.)	38	50	37	55	60	53

Cold caustic soda semi-chemical pulp

Total fibrous matter (%)	87.2	86.6	85.1	89.7	87.1	89.5
Apparent density	0.701	0.808	0.701	0.771	0.731	0.799
Breaking length (m.)	4,870	6,630	4,880	5,970	4,920	5,790
Stretch (%)	1.94	2.52	2.00	2.33	2.17	2.25
Bursting strength (m^2)	20.5	30.4	20.7	27.7	21.4	25.3
Folding strength (No.)	15	100	8	52	19	39
Breaking load (grams)	43.8	47.5	46.7	42.6	46.7	43.1
Refining (min.)	57	58	49	57	58	49
Degree of brightness	high	weaker	high	high	weaker	high

VENEER INDUSTRIES

Poplar veneer industries started when this species began to be used for the manufacture of matches but their present development is mainly due to the constant increase in the consumption of plywood.

Cautious experiments had continued for a long time in several countries but it was in Italy in about 1936, as a result of circumstances which interfered with its supply of okoumé and birch, that the large-scale manufacture of poplar plywood was begun. There was some uncertainty at the outset but since the products met the needs of the home market, rapid expansion followed; factories, which numbered some 30 in 1936, in 1954 numbered over 120, and poplar is now used for more than 90 percent of all veneers. During and after the second world war, other countries followed Italy's example and poplar is now used for plywood in almost all countries, the total consumption being probably in the region of a million cubic meters.

Matches

In northern Europe, *P. tremula* is used; in the south, *P. alba* would be suitable if it were not for its gummy zone. Black poplars and Euramerican hybrids are in general use everywhere.

In match factories, either sticks or boxes are made: for the former and particularly for books of matches, choice wood free of defects is absolutely essential. The good wood is used for the outer box cases, the fairly good quality for the drawers and the rest for the bottoms.

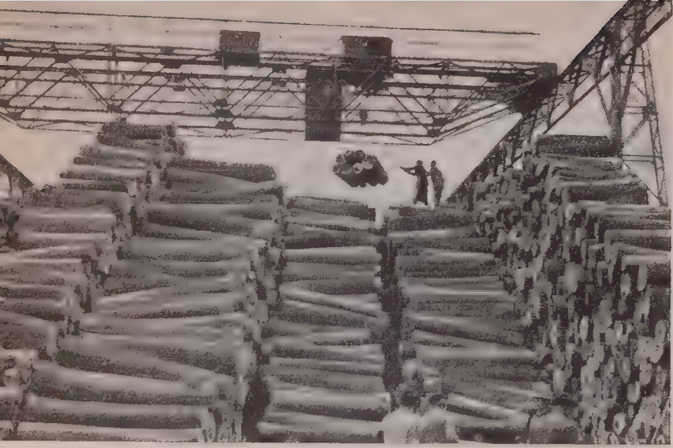
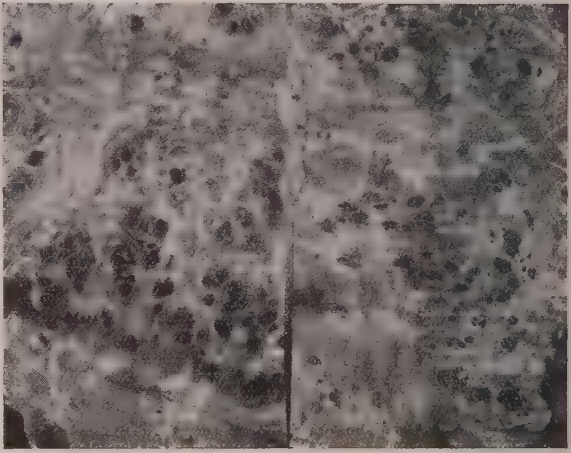


FIGURE 255. – Poplar plywood logs stacked at a factory in north Italy.

Courtesy *G. Giordano*

FIGURE 256. – Slices through burrs of *P. nigra.*

Courtesy *G. Giordano*



Plywood

No particular comment is needed on the use of poplar wood in this industry. One of its great advantages is that owing to the high moisture content of the wood, the logs do not need to be steamed beforehand. As the wood is easy to peel, sheets ranging in thickness from 0.2 to 6 millimeters can be obtained. During drying, the color difference between the sapwood and the heartwood diminishes; on the other hand, sheets with tension wood warp, buckle and often crack. *P. alba* causes difficulties on account of the gummy substances between the layers of sapwood and heartwood. Attempts have been made (in Austria and Spain) to eliminate this coloration by steaming and other processes. *P. tremula* and typical *P. nigra* are used only to a small extent for plywood; on the other hand, American poplars and Euramerican hybrids have a high value.

In gluing, good results have been achieved with all the known glues. Blood albumin, however, cannot be used with layers which are too thin if discoloration of the surfaces is to be avoided.

There is wide divergence in market demand for finished products. Whereas in the United States, poplar is used almost exclusively for the interior of the boards, in Europe boards are also made entirely of poplar. In Italy the most usual types are three-ply boards, 3 or 4 millimeters thick.

Sometimes plywood is also made from cut veneers, as are the famed grained woods (*Maserpappel*) obtained from the butt logs of certain *P. nigra* in the Rhineland.

In France a small vertical cutter is used to salvage the waste from the core of billets peeled for veneer. It is used in box making.

Light box-making material

Since most seasoned poplar wood is odorless, light-colored and can be bent when thin, it is often used as a material for light box making in the form of thin veneer sheets cut into strips a few centimeters wide, made into hampers and fruit baskets, or round boxes for cheese, jam, cosmetics, etc.

The manufacture of the usually round, so-called cheese boxes is of great importance in some countries: in France alone it is estimated that daily production exceeds 1,000,000 boxes.

The steps in its manufacture are as follows:

1. Unloading of logs from trucks, stacking in yards, picking up and conveying to the sawmill by travelling crane.
2. Crosscutting with chain saw, grading (selection of butts for use in the plywood factory), or cutting to size lengthwise (according to the size of the boxes). The best logs are used for making thin veneers (2 to 6/10 mm.) for box rounds and the others for making thick veneers (2.4 to 6 mm.) for the bottoms of the boxes and small cases.
3. After crosscutting, the wood is barked by hand and veneer-peeled in fresh state (unsteamed). In winter it is "thawed" in pits into which steam is injected. There are several veneer lathes, depending on the length of the billets: that for making

box rounds marks little grooves on the veneer which will serve later for bending the round (this is known in America as " tenderizing ").

The peeled billets (whose diameter fits the clamps, provided they are without serious flaws) are either cut by saw or vertical cutter in another workshop to make little boxes, or are sent to the pulp factory.

The veneer sheets coming off the lathes are passed to the trimmers which cut them into standard lengths (for the boxes) or into standard grades (elimination of certain flaws).

Drying is done either in the open (for this purpose screens are used to prevent the veneers from buckling and to shelter them, so that they do not dry too quickly), or in a drying tunnel. When the veneers are dry, they go to the box-making workshops, where the other operations are carried out (cutting out, bending, clamping, etc.). Machining waste goes to the pulp factory.

Poplar is widely used in the preserved food industry in Italy, and special machines have been designed for making plywood containers in the shape of a truncated cone.

Other uses

Veneers today are put to numerous uses other than those already mentioned. In Italy, for example, there is a wide demand for flat wooden spoons and forks, for picnic baskets, and for supports for ice creams, enabling one to hold the ice while tasting. A single factory in Milan manufactures 8 million such articles a year.

The most serious defects for the veneering industry are tension wood, damage due to fungi and insects, knots and any irregularity in the tissues. For matches, it is also necessary to include twisted fibers, dormant buds and figured or wavy grained wood.

An unfavorable factor, which cannot be termed an actual defect but rather a negative characteristic, is the tendency for veneer sheets to tear longitudinally along the fibers. This may occur at the slightest resistance to longitudinal cutting, as has already been mentioned by Chardenon. It is a characteristic which is more common in some clones than in others, and is more frequently found in frozen wood.

Logs which are crooked or have an irregular section should not be used for veneer peeling, nor should those with a diameter below a certain limit, as wastage increases considerably with decrease in diameter.

The importance of a good choice of material and of its proper preservation must be stressed; often no precautions are taken to protect stocks from fungi, which may cause serious damage. In some plywood factories in northern Italy, *Pholiota* and *Stereum* have damaged 15 percent of the total stock volume in wet years.

The small billets or cores which are left after veneer peeling are often resawn to obtain small boards for packing cases or similar uses. While the use of such waste billets for the manufacture of paper and cellulose pulp has not so far proved satisfactory, their use as building boards has given interesting results.

The output of finished products obtained from poplar in a plywood factory depends on several factors, chief among them being the choice of logs, their diameter and efficient organization of the work.

If the logs show defects such as holes made by xylophagous insects, tension wood, irregular section, frost cracks, canker, bacteriosis, etc., the output falls to a very low level. For this reason, the industries concerned keep a careful check on the timber parcels in the forest immediately after felling, to ensure that only suitable logs are accepted.

As regards diameter, a 10-centimeter core represents a wastage of:

4 % if the log is 50 centimeters in diameter
8 % " " " 35 " "
16 % " " " 25 " "

Logs with a diameter of less than 35 centimeters should therefore be avoided as far as possible. Without going into detail here, an important consideration in efficient work planning should be the salvage of waste. This applies not only to the actual cores of the billets but also to the waste which occurs during the rounding and trimming operations, as well as from kilns and in the panel finishing.

In plywood factories which accept poplar logs 25 centimeters in diameter or over, the yield in finished products is about 35 percent of the initial volume, including bark. Even without taking into account the cores which are sawn or sliced, there is a large amount of waste material, which in some factories is used for fuel, though this is not the most economic solution.

However, such a by-product is difficult both to store and transport, particularly if there are no pulp or fiberboard factories to use it in the vicinity. Shredding also involves undeniable but not insuperable difficulties.

Mention should be made here of research which has been carried out at the *Centro Sperimentale Cellulosa* of Rome on a clone which is widely distributed in Italy (the ' I-214 '). Experiments have shown that the longest fibers are in the wood at the base of the tree and in the outer layers. Waste from rounding butt logs would therefore be suitable for conversion into pulp.

BUILDING BOARDS INDUSTRY

Strong boards with poplar lath cores are made directly from plywood. A fairly recent, very original type has no real core through the whole of the area but the two outer plies are held in position by pieces cut lengthwise. As there is less variation of length in the axial direction, surface irregularities and buckling are reduced to a minimum.

Owing to the ease with which it can be worked, poplar wood is widely used in the manufacture of wood wool boards, which are of great importance in temporary constructions or as heat and sound insulators. Cement and lime are the chief binding materials.

The specifications of an Italian product of this kind (*Populit*) are: thickness, from 15 to 60 millimeters; weight of 1 cubic meter, from 300 to 500 kilograms.

The use of poplar for fiberboards is not yet very common, the small length of the fibers, compared with softwoods, being a disadvantage. Nevertheless, poplar can be mixed with the latter in the proportion of 1 : 9, and in Belgium a factory is in fact producing poplar fiberboards (*Unalite*).

For boards made of waste, bound with synthetic resins, the prospects of using poplar wood are very good. In Germany, a kind of board (*Behrplatte*) is being manufactured in which the two outer surfaces are covered with poplar wood to give the finished product color and a good appearance.

MISCELLANEOUS INDUSTRIES

Box making

Mention has already been made in the sections on sawing and veneer peeling, of the use of products from these industries for box making. It may also be pointed out that wood wool is widely used for padding fragile articles (glassware, mirrors, etc.). There are several grades, according to the quality of the wood (more or less light in color, presence of defects) and the size of the chips.

The most serious defects in the manufacture of wood wool are knots, discoloration, insect attack and tension wood.

Sabots

The use of poplar wood for the manufacture of footwear is very old, and in some regions (Belgium, the Netherlands, Germany, France, Italy) the peasants still wear sabots made from this species. Sometimes only the soles are of wood, as in the Near East and Syria.

The species most valued for resistance and durability are *P. tremula*, *P. alba* and *P. canescens*, followed by *P. nigra* and the Euramerican hybrids. The hybrids are generally easier to work, being softer than the others. The logs must be at least 15 centimeters in diameter.

Waste during manufacture is always very high, even if the wood is almost free from defect.

Wood flour

Poplar wood, except for *P. alba* and its hybrids, yields a valuable flour that is used for the same purposes as any other wood flour (plastics, soap, sanitary products, insecticides, fireworks, etc.).

Straw of poplar

A little-known use of poplar wood but one of great importance in part of the Po Valley is that of small shavings known as "poplar straw."

This use dates back to the beginning of the sixteenth century, but whereas willow was employed exclusively up to the end of the last century, today only poplar is used, generally cultivated hybrids, together with a small amount of *P. tremula*. The logs must be between 15 and 40 centimeters in diameter and first class in every respect (without knots, tension wood, color stains, insect damage; the colored duramen must not exceed 10 centimeters). The usual practice is to transport the unbarked logs (4 meters in length) from the forest and stack them in a cool place. They are cut into billets 45 to 46 centimeters long just before they are to be used. With a primitive machine the worker cuts strips in the direction of the fibers, on the surface of a log which is made to turn on its axis. The shavings which are 0.5 millimeter thick and 2.5 to 9 millimeters wide, are bleached with sulphur and hand-plaited by women, who often perform this work walking about. Speed of production is about 45 meters per hour for the three-strand or simplest type. The finished plaits are 40 to 72 meters long, and vary widely in pattern and type. Multicolored plaits are also made with aniline-dyed "straw."

The plaits are used for making sunbonnets (worn locally by the peasants), hats of all shapes and quality, mats, baskets, bags for women, light footwear for women and children, and even neckties for men.

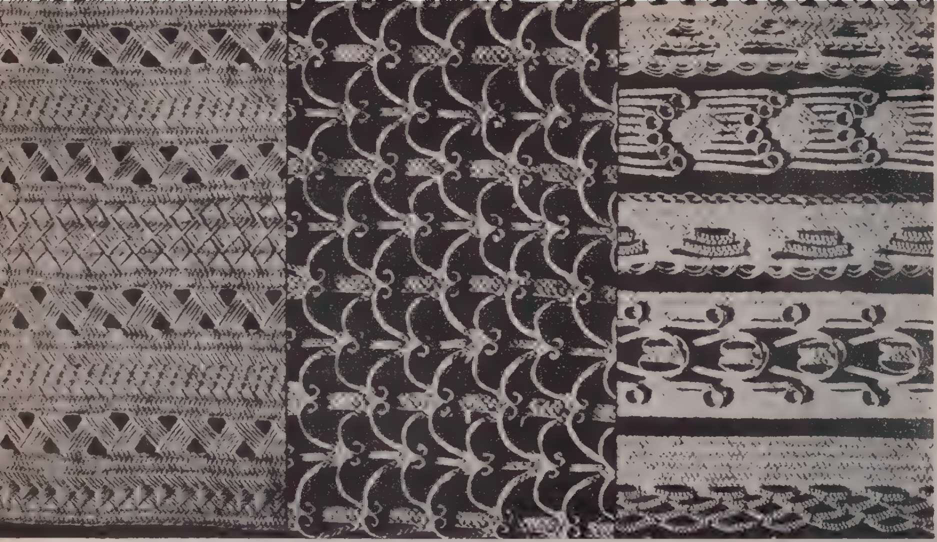


FIGURE 257. – Examples of work in "poplar straw," carried out on the plain of the River Po.

Courtesy *G. Giordano*

Orthopedic articles

The ease with which it can be worked and the light weight of poplar wood make it very suitable for prosthetic appliances (especially artificial legs).

Electrical and chemical industries

The absence of substances in the cells (with the exception of *P. alba* and its hybrids) make poplar suitable for the manufacture of vats for chemical solutions, and its homogeneous structure also allows it to be used as separators in accumulators.

Musical instruments

The wood of *P. alba* has long been used for certain piano parts, as well as for the backs and sides of violins, double-basses and other string instruments. For these purposes grained wood is particularly valuable.

Uses in agriculture and artisan crafts

Poplar branches are frequently used as props, stakes, etc. for farm crops (beans, hops, tomatoes, peas). The peasants also make a large number of objects and implements from the wood, such as ladders, troughs, pipes for pumps, wooden spoons, spindles, hurdles for drying produce, etc.

BY-PRODUCTS OF POPLAR STANDS

Poplar wood is also used for fuel; in addition, the stands yield by-products other than wood.

Fuelwood

Poplar wood does not make very good fuel because it does not kindle quickly, despite its light weight. Nevertheless, it is of great importance in this respect, because in some intensive farming regions or in countries almost devoid of wood supplies, for example in the Near East, it is the only wood producer. The pollards so often seen in these regions are in fact like coppice, which provide a considerable amount of fuelwood over very short rotations (two to three years).

Charcoal made from poplar wood is highly valued medicinally for intestinal disorders, in some industries as a filter, and for black powder.

By-products other than wood

In some areas fallen poplar leaves are collected for litter, and in others the fresh leaves provide forage for cattle: sheep apparently show a preference for *P. nigra* cv. ' italica ' and cows for *P. deltoides*. A comparative analysis provides the following data:

Constituents	Lucerne %	Grass %	Poplar leaves %
Water	74.0	80.0	60.0
Minerals	2.0	2.0	4.1
Fats	0.8	0.8	1.9
Nitrates	4.5	3.5	6.2
Non-nitrogenous extracts	9.2	9.2	23.2
Cellulose	9.5	4.5	5.2

The question is one worth following up, and might have considerable economic and social importance in countries without adequate supplies of forage.

The thick bark of certain poplars is used as floats for fishing nets on some lakes in Switzerland.

In poplar stands of the Piedmont plain (north Italy) highly valued white truffles are sometimes found (*Tuber magnatum*); some authorities believe that there is a true symbiosis between truffle and poplar.

APPENDIX 1

TECHNOLOGICAL TEST FORM *

Docket No. ....
No. of sample .... Botanical name........ Local name ....
(If possible, attach specimens of buds, leaves, flowers)

I. STAND CHARACTERISTICS AND FORESTRY INFORMATION

Station:

Climate (by reference to a known international classification) ...
Locality.....................
Altitude.....................
Prevailing wind ....
Position of stand ....
Arrangement of trees ....
....

Soil:

Texture { clayey / silty / sandy (strike out whichever is not applicable)
Reaction { calcareous / noncalcareous
Content in organic matter ...
pH ....
Porosity { capillary / noncapillary / moisture content
(by Kopecky's method, simplified by Siegrist - Mr. Oudin's apparatus)
Water level ....

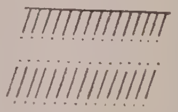
Cultural conditions:

Forestry information:

Date of felling ....
Date of hauling ....
Date of crosscutting ....
Date of forwarding samples ..
Age of tree (distinguishing between years in nursery and years in plantation) ....

Storage conditions:

Cross section of soil



(if this has not already been indicated in the diagrams showing cross section of soil)

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* Since the publication of the French edition, the technological test form has been modified by the International Poplar Commission at its Ninth Session in Paris, 1957. The form as approved is reproduced above.

II. SAMPLES

It is recommended that, if possible, measurements over bark and under bark be given (of diameter or circumference) of the sections of the tree:

at ground level, at a height of 2 meters, 4 meters, etc.

so that an exact reconstruction of the tree may be made; details should also be given as to the inclination of the trunk and the form (symmetrical or asymmetrical, spread, fastigiate, etc.) of the crown.

For laboratory test

The sample sent to the laboratory shall be in the form of a log, minimum length 1.2 meters (4 ft.); or, should that be impossible, of a board cut longitudinally from the center of the log at its widest point; depth 7 centimeters, breadth equal to diameter, length 1.2 meters. Indicate the part of the tree from which the sample is taken (butt logs, top logs, large branches, etc.). In any case, the sample may not be taken from the butt log bearing the root buttresses (unless the wood is intended solely for the fabrication of paper). If the different parts of the tree are in general destined for several industries, at least one log for each type of use should be sent.

For industrial tests

The samples necessary for industrial tests will have to be cut according to the requirements of the industries concerned.

III. LABORATORY TEST - DESCRIPTION OF THE WOOD

1. *Chemical analysis of the wood*

Preparation of the samples ....
Water solubles ....
Alcohol/benzene solubles ....
Cellulose content ....
Pentosan content ....
Lignin content (sulphurical method) ....
Content of ash and secondary constituents (fats, starch, etc.) ....
....

2. *Micrograhic study of wood anatomy*

Distance between annual rings { maximum ....
minimum ....
average ....

Texture: ....

Dimensions and distinguishing features of constituents:

Vessel segment: Diameter ....
Length of constituents ....
Number in 1 mm^2 ....
Differences, if any, between sap- and heartwood ...

Fibers: Diameter ....
Length (attach a diagram showing frequency of lengths) ....
Relation between length and diameter ....
Thickness of walls ....

Medullary rays: Type ....
Number of cells in the height of the ray ....
Height..
Width ....
Number of rays in 1 millimeter in a tangential direction ....

(Give, if possible, the distribution of gelatinous fibers in the transverse section)

Other peculiarities of the tissues (structural anomalies, secretions, etc.)...

Transverse section *Radial section* *Tangential section*

Photomicrographs

3. *Physical and mechanical study*

All determinations should be made, in accordance with the recommendations of the FAO Commission on Mechanical Wood Technology, at 12 percent moisture content in the wood (based on the oven-dry weight of the wood). If it is not possible to obtain a moisture content of 12 percent in the test specimens, the moisture content at which the tests have been made must be indicated, adding, if possible, the correction factors necessary to convert the data to 12 percent moisture content.

Density based on oven-dry weight and volume at a moisture content of 12 percent ....
Density based on oven-dry weight and volume ....
Basic density[1] (relation between oven-dry weight and green volume) ....

Radial shrinkage } figures for green volume ....
Tangential shrinkage } moisture content of at least ....
Total volumetric shrinkage } 30 percent – and oven-dry state ......
Janka hardness ....
Strength value (for each type of stress application indicate the dimen-

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[1] It should be stated whether the green volume has been measured on freshly cut wood or on wood which has been immersed in water, so that the internal tensions may be exposed.

sions of the test specimens, the method followed and the number of tests). The determinations made should be at least the following:

a) compression parallel to the grain test ....
b) bending test..
c) shear parallel to the grain test.................................
d) impact test ....

IV. Industrial tests - Technological characteristics

1. *General characteristics of logs*

a) External appearance of each log examined:
  Bark ....
  Ledges, external knots, etc.
  Fissures, bends ....

b) Appearance of cross section of log when cut:
  Bark ....
  Color of wood
    in the sapwood ....
      (thickness of sapwood)
    in the heartwood .....
  Centering of pith ....
  Whitish or cottony marks due
    to tension wood ....
  Knots ....
  Ring shakes ....
  Brown marks due to bacteriosis or to other reasons .
  Other defects.............

Cross section of bark

2. *Machining tests*

a) Sawing:

Conditions of sawing:
  Type of saw and of blade ....
  Teeth (type and number) ....
  Saw speed ....
  Rate of advance of the log.............................

Reaction of the wood while being sawn:
  Deformations, cracks, etc. ....
  Power absorbed ....

Appearance of sawn timber:
  Color ....
  Knots and faults ....
  Tension wood ....

Straightness of grain ....

Peculiarities ....

Reaction of sawn timber to drying:

Deformation, cracks...

Speed of drying...

b) Machining tests other than sawing:

Difficulties or pecularities encountered: state of the surfaces, etc., during the following operations:

Surfacing ....

Planing (indicate the characteristics of the tools used) ....

Working by hand (indicate the characteristics of the tools used)

Suitability for nailing ....

Assessment of the machining qualities of the wood ....

Suitability for gluing..

3. *Peeling tests*

Moisture content at time of peeling ....

Quality and color of sheets as peeling proceeds ....

Wood brittle or otherwise (lathe checks) ....

Sharpness of groove line ....

Internal knots and other faults ....

Reaction to drying – color after drying ....

Other remarks...

Assessment of the peeling qualities of the wood, with reference to the product to be obtained ....

4. *Paper manufacturing tests*

Micrographic study	if necessary, *see* paragraph III above, showing standard paper-making characteristics of the pulps, semi-pulps and cellulose	....
Chemical analysis		....
Grinding tests		....
Cooking tests		....

Felting capacity ....

Assessment of the paper manufacturing qualities of the wood ....

APPENDIX 2

FORM FOR MEASUREMENTS ON POPLAR WOOD SAMPLES AT TIME OF FELLING

Country ....

No. of tree .... No. of sample .... Local name .... (1)

1. STAND CHARACTERISTICS

a) *Site:*

Place where sample is taken

Altitude

Prevailing wind

Soil: provide information obtained by examination with the naked eye, not forgetting the water supply available to the tree during its lifetime (irrigation, periodic flooding, water table, etc.)

b) *Structure composition:*

Arrangement of trees

Density of stand

Dimensions of average tree

Age of trees (if possible, on the basis of direct information but always giving the number of growth rings)

2. POSITION ON FELLED TREE IN THE STAND

3. INFORMATION ON LOGGING

Age at which stands are normally felled. . . . .

Season at which stands are normally felled. . . . .

---

(1) If possible, attach full identification form.

Felling tools used. . . . .
Lopping tools used. . . . .
Bucking tools used. . . . .
Equipment, animals and vehicles used for haulage and transport

4. Description of sample at time of felling

Date of felling and bucking. . . . .
Height above ground at which billet is taken. . . . .
Bark (color, furrows, pustules, ease of removal). . . . .
Centering of pith. . . . .
Defects, if any. . . . .
Knots . . . .

5. Measurements of billet on the spot at the date of:

	Unbarked	*Barked*
weight	. . . . . .	. . . .
circumference of butt end of the billet (to the nearest mm.) *a*)	. . . . . .	. . . .
circumference of top end of the billet (to the nearest mm.) *b*)	. . . . . .	. . . .
distance along axis between *a*) and *b*) (to the nearest mm.)	. . . . .	
average total length of the billet (to the nearest mm.) for determination of apparent volume and, consequently, of density in green condition	. . . . .	

Remarks

(1) Taking of the billet:

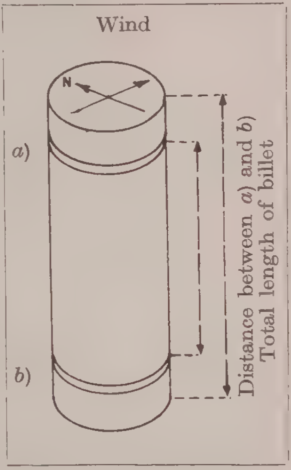
The billet should be 1.10 meters long and taken halfway between the base and the first larger branches; immediately after felling, it should be bucked, weighed and measured with and without bark.

(2) Measurements:

Use should be made of a flexible measuring tape for the circumference measurement, and the billet should be marked with a knife along the two edges of the tape so as to facilitate subsequent measurement at the same place in the laboratory.

(3) Marking of the billet:

The top end of each billet should be marked with a black arrow to indicate the North position of the standing tree and a red arrow to indicate the direction of prevailing winds. The butt end should be marked with an identification letter for the country, the number of the tree, and the number of the sample where two billets are taken from the same tree.



ALPHABETICAL LIST OF POPLAR SPECIES, VARIETIES AND CULTIVARS

The names of species and natural varieties are given in italics; cultivated varieties (or cultivars) by normal lettering between single inverted commas.

In the list it is understood that the last word (s) indicates the name. For example, the reference to *Populus tremula*, *Populus alba*, var. *nivea* and *Populus* x *euramericana* cv. ‘serotina’ are to be respectively sought under *tremula*, *nivea* and ‘serotina’.

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